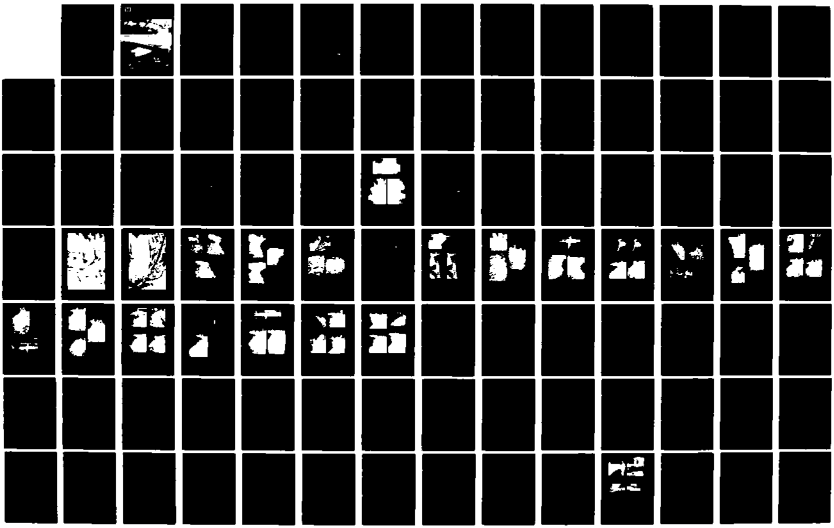
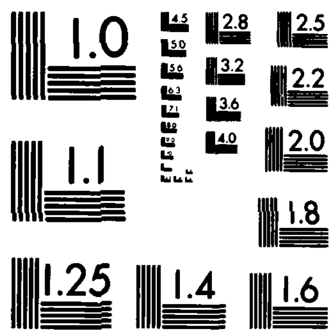
AD-A121 134 THE STREAMBANK EROSION CONTROL EVALUATION AND DEMONSTRATION ACT OF 1974 S..(U) ARMY ENGINEER WATERWAYS EXPERIMENT STATION VICKSBURG MS HYDRA.. 1/4

UNCLASSIFIED M P KEOWN ET AL. DEC 81 WES/TR/H-77-9-APP-D F/G 13/2 NL




1.0
4.5
5.0
5.6
6.3
7.1
8.0
9.0
2.8
3.2
3.6
4.0
2.5
2.2
2.0
1.1
1.8
1.25
1.4
1.6

12

US Army Corps of Engineers

December 1981

THE STREAMBANK EROSION CONTROL EVALUATION AND DEMONSTRATION ACT OF 1974 SECTION 32, PUBLIC LAW 93-251

Appendix D - Ohio River Demonstration Projects

Rock Toe With Tie-Backs

Precast Block Paving

Board Fence Dikes

Unclassified
SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

REPORT DOCUMENTATION PAGE		READ INSTRUCTIONS BEFORE COMPLETING FORM
1. REPORT NUMBER Technical Report H-77-9	2. GOVT ACCESSION NO. AD-A121134	3. RECIPIENT'S CATALOG NUMBER
4. TITLE (and Subtitle) LITERATURE SURVEY AND PRELIMINARY EVALUATION OF STREAMBANK PROTECTION METHODS		5. TYPE OF REPORT & PERIOD COVERED Final report
		6. PERFORMING ORG. REPORT NUMBER
7. AUTHOR(s) Malcolm P. Keown Noel R. Oswalt Edward B. Perry Elba A. Dardeau, Jr.		8. CONTRACT OR GRANT NUMBER(s)
9. PERFORMING ORGANIZATION NAME AND ADDRESS U. S. Army Engineer Waterways Experiment Station Hydraulics Laboratory, Mobility and Environmental Systems Laboratory, Soils and Pavements Laboratory P. O. Box 631, Vicksburg, Miss. 39180		10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS Work Unit 02
11. CONTROLLING OFFICE NAME AND ADDRESS Office, Chief of Engineers, U. S. Army Washington, D. C. 20315		12. REPORT DATE May 1977
		13. NUMBER OF PAGES 262
14. MONITORING AGENCY NAME & ADDRESS(if different from Controlling Office)		15. SECURITY CLASS. (of this report) Unclassified
		15a. DECLASSIFICATION/DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT (of this Report)

Authorized for public release; distribution unlimited.

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

18. SUPPLEMENTARY NOTES

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

Bank erosion
Bank protection

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

A preliminary study of streambank erosion control was conducted with the major emphasis on an extensive literature survey of known streambank protection methods. In conjunction with the survey, preliminary investigations were conducted to identify the mechanisms that contribute to streambank erosion and to evaluate the effectiveness of the most widely used streambank protection methods. The results of the literature survey and the two preliminary investigations are presented herein.

(Continued)

DD FORM 1 JAN 73 1473 EDITION OF 1 NOV 65 IS OBSOLETE

Unclassified
SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

20. ABSTRACT (Continued).

The text of the "Streambank Erosion Control Evaluation and Demonstration Act of 1974" is presented in Appendix A. A list of commercial concerns that market streambank protection products is provided in Appendix B. Appendix C contains a glossary of streambank protection terminology. A detailed bibliography resulting from the literature survey is provided in Appendix D, and a listing of selected bibliographies related to streambank protection are provided in Appendix E.

FINAL REPORT TO CONGRESS

THE STREAMBANK EROSION CONTROL EVALUATION AND DEMONSTRATION ACT OF 1974 SECTION 32, PUBLIC LAW 93-251

APPENDIX D
OHIO RIVER DEMONSTRATION PROJECTS

Consisting of

A BRIEF SUMMARY REPORT AND INDIVIDUAL EVALUATION REPORTS ON NINE STREAMBANK EROSION CONTROL DEMONSTRATION PROJECTS ON THE OHIO RIVER

U.S. ARMY CORPS OF ENGINEERS
December 1981

APPENDIX D

Ohio River Demonstration Projects

CONTENTS

Appendix D
Ohio River Demonstration Projects
Section 32 Program

Summary

The Final Report to Congress on the work done under the authority of the "Streambank Erosion Control Evaluation and Demonstration Act of 1974" consists of a Main Report and eight Appendices. The Main Report is an overall presentation of the study with a summary of pertinent findings, conclusions, and recommendations. The appendices provide specific information on the various items presented in the Main Report.

This Appendix D covers the design, construction and monitoring details of the nine Ohio River demonstration projects constructed under the authorizing legislation. Three projects constructed on tributaries of the Ohio River are reported under "Demonstration Projects on Other Streams, Nationwide" in Appendix G.

The Pittsburgh, Huntington and Louisville Districts were responsible for the design and construction of the projects according to their geographical location within the Ohio River Division. Performance monitoring of the projects constructed has been accomplished by the districts. Details of the observations are covered in the project reports in this appendix, which were prepared by the respective districts and reviewed by the Division Office.

Reports on Demonstration Projects

	Main Report Map No.
Pittsburgh District	
Moundsville Grave Creek, West Virginia	1
Moundsville Country Club, West Virginia	2
Powhatan Point, Ohio	3
Huntington District	
St. Mary's, West Virginia	4
Ravenswood, West Virginia	5
South Point, Ohio	6
Portsmouth, Ohio	7
Louisville District	
Moscow, Ohio	8
Mt. Vernon, Indiana	9

Local cooperation agreements with the various sponsors in accordance with Section 221 of the Flood Control Act of 1970 (Public Law 91-611) has been executed by the various districts. An environmental assessment in accordance with Section 404(b)(1) of the Clean Water Act was made for every project and is on file with the respective districts. See example on pages D-5-24 to D-5-27.

OHIO RIVER AT
MOUNDSVILLE (GRAVE CREEK), WEST VIRGINIA

Section 32 Program Streambank Erosion Control
Evaluation and Demonstration Act of 1974

OHIO RIVER AT MOUNDSVILLE (GRAVE CREEK), WEST VIRGINIA
DEMONSTRATION PROJECT PERFORMANCE REPORT

I. INTRODUCTION

A. Project Name and Location. Moundsville, West Virginia, Grave Creek Demonstration Project, Ohio River - Mile 102, at Moundsville, W.V. Plate 1 shows the project location.

B. Authority. Streambank Erosion Control Evaluation and Demonstration Act of 1974, Section 32, P.L. 93-251.

C. Purpose and Scope. The report describes a bank erosion problem, the types of protection used, and a performance evaluation of a demonstration project on the Ohio River designed and monitored by the Pittsburgh District.

D. Problem Resume. The left bank of the Ohio River was subject to active erosion which was undercutting mature trees and land which was leased at the time of construction by the City of Moundsville for public recreation and by an asphalt production facility. The site is crossed by a sanitary sewer, running parallel to the bank, which would be endangered if erosion were to continue.

II. HISTORICAL DESCRIPTION

A. Stream Description, General.

1. Topography. The Ohio River at the demonstration site drains an area of 25,500 square miles covering primarily Pennsylvania west of the Allegheny Mountains and extending into portions of Ohio, West Virginia, New York, and Maryland. Major tributaries are the Allegheny, Monongahela, and Beaver Rivers. The topography of the basin is characterized by mature development of the drainage systems within the Allegheny plateau

physiographic province. From its origin at Pittsburgh the river descends 90 feet along a course of 102 miles to the demonstration site. Relief at the site is approximately 700 feet from the river to the top of the surrounding valley walls. The river flows south at the demonstration site following a sinuous course with curves varying from 45 degrees to 180 degrees and radii of 1 to 2 miles. The natural stream gradient in this area is about 0.5 foot per mile. The valley floor averages about 0.6 mile in width. Stream banks average from 17 feet at Wheeling to several feet above normal pool at the Hannibal Lock and Dam. The Moundsville Grave Creek demonstration site is near the downstream end of the Moundsville Bottom which extends along the river for 3.5 miles on the outside of a sharp southeastern bend.

2. Geology. The Ohio River throughout its course along the West Virginia-Ohio border has become entrenched in sedimentary strata of Pennsylvanian and Lower Permian Age. These strata are made up of interbedded sandstones, siltstones, clays, shales, limestones, and coals. The bedrock valley of the Ohio River contains an alluvial fill of outwash from the Wisconsin continental Glacier. In the portion of the Ohio Valley within the study area the alluvial fill is predominantly gravel, sand and gravel, and gravelly sand. Since the last glacial episode, the Ohio River has been cutting down through the alluvium with the formation of river terraces at various elevations in the Wisconsin fill and a well defined flood plain. In the study area, the Ohio River is still underlain by the Wisconsin alluvial fill to depths of 35 to 60 feet. A layer of fine grained alluvium, averaging 10 to 30 feet in thickness, has been deposited on the flood plain by inundations of Ohio River floodwaters.

The Ohio River channel has been shifting back and forth across the alluvium which fills the bedrock valley. The channel is thus frequently located asymmetrically on one side of the old bedrock valley. In these areas, one bank consists of the highly erodible flood plain deposits and the other consists of rock out-crops or colluvial soil which has accumulated through weathering and creep of the hillsides above. The collu-

vial soils are generally stiff to hard silty clays with angular rock fragments and little or no layering. These soils tend to resist erosion and seem to erode at a much slower rate than flood plain deposits.

Moundsville Bottom, on which the demonstration project is located, is a flood plain which features an abondoned cut-off meander channel of the Ohio River which extends 1.5 miles eastward from the present channel location. A boring made for the installation of piezometers at the demonstration site encountered rock under 41 feet of alluvium and colluvium, at elevation 595, while water supply wells at the State Penitentiary, located eastward in the middle of the meander area, reportedly penetrated 100 feet of gravel, to elevation 580, without encountering bedrock.

3. Locality, Development, and Occupation. The Ohio River Valley in the vicinity of the demonstration site has developed a diverse industrial character. Over the past several decades most of the broad agricultural bottoms have been acquired for industrial development. Within the Hannibal navigation pool the river valley contains several large cities and towns, including Wheeling, Moundsville, and New Martinsville in West Virginia, and Martins Ferry, Bellaire, and Shadyside in Ohio. Local industries include coal mining, steel, chemical and aluminum production, electric power generation, and a variety of light manufacturing. The river is paralleled by railroads and highways on both banks.

The Ohio River has been an important transportation artery since pre-history and has undergone navigation improvements since 1824 when Congress provided for removal of obstructions such as bars and snags. For many years river navigation was facilitated solely by open channel improvements. In addition to removal of channel obstructions, stone training dikes were constructed at various bars in order to constrict the channel and increase the scour of the river. The first movable dam on the Ohio River was located at Davis Island, 4.7 miles below Pittsburgh, and opened to commerce October 7, 1885. A system of locks

and movable dams was eventually constructed along the entire Ohio River. In August 1917, Lock and Dam 14 was put into operation 12 miles downstream of the demostration site. These early dams incorporated a navigable pass to provide a channel for open river navigation during periods of high flow. A series of wickets, heavy timber shutters, were raised to impound water as needed to maintain a navigation pool. When not required, the wickets would lie flat at such a depth as to offer no obstruction to free navigation through the pass. Replacement of these original navigation dams with fixed, gated structures having higher lifts has been ongoing. In 1975, Hannibal Locks and Dam went into full operation and Locks and Dams 12, 13 and 14 were removed.

4. Hydrologic Characteristics. The Ohio River Valley in the vicinity of the demonstration site is subject to a continental climate with high and low temperature extremes of 95 degrees to 105 degrees F., and -15 degrees to -25 degrees F. The mean annual temperature averages 50 degrees F. The growing season extends from late April to mid-October. Normal annual precipitation is approximately 40 inches per year. The flood of record occurred in March 1936 with a maximum discharge of 450,000 c.f.s. in the vicinity of the demonstration site. This flow exceeded the 500-year flood and, at the demonstration site, overtopped the bank by 12 feet. A stage frequency curve is shown on Plate 2. A one-year flood hydrograph is shown on Plate 3.

5. Existing Channel Conditions. The sinuosity of the channel was described in paragraph II.A.1. The channel location has been relatively stable within historical time. A discharge rating curve for the river at the site location is shown on Plate 2.

6. Environmental Considerations. A minor amount of farming is practiced in the few remaining undeveloped portions of the river valley. This is being accomplished under lease from the industries in the area who own these properties and are reserving them for future expansion of facilities. The steep hillsides adjacent to the valley floor are pri-

marily undeveloped and consist of second growth woodlands. Within the flood plain, vegetation associated with farming and frequent site disturbance prevails. Along the river bottom land, silver maple and sycamore occur most frequently, while elm, cottonwood, buckeye and willow are present with somewhat reduced representation. On the hillsides and in areas of greater stability above ordinary high water, oaks, beech, red maple, ash, black cherry and walnut exist. Timber stands adjacent to the river are generally of low quality because of physical damage caued by ice and floating debris during high water. Nails, spikes, eye bolts, cables and physical damage from river traffic are also evident in many specimens.

Both fish and wildlife resources of significance are found in the project area. Fishes include such species as channel catfish, carp, spotted bass, largemouth bass, smallmouth bass, white bass, pumpkinseed, bluegill, white crappie, shiners, perch, skipjacks, gizzard shad, and golden redhorse. Excellent warm-water fisheries have developed at or near the mouths of several of the tributary streams. Wildlife resources also include a variety of species. Mourning doves, bobwhite quail and cottontail rabits are present in the agricultural areas, while ruffed grouse and squirrels inhabit the uplands. White-tailed deer are present in the adjacent uplands and also range into the valley. The Ohio River also provides resting and feeding opportunities for several species of migratory waterfowl. Muskrat, mink, raccoon and fox are some of the fur animals in the area.

This reach of the river, as with the entire Ohio in general, is exposed to various types of pollution which tend to affect aquatic life and generally detract from the aesthetic value of the river. Excessive amounts of organic matter, chemicals, sediment and colloidal particles contribute to the relatively poor water quality, with seasonal variations experienced as a result of changes in flow and temperature.

The use of steel furnace slag in the demonstration schemes may also result in a level of water quality degradation commensurate with the

bulk chemical content of the slag and the availability of its chemical constituents to the Ohio River as a result of leaching and weathering. Fines may also enter the Ohio River as a result of slag erosion.

Plate 4 provides a comparison of results of leachability tests performed on slag used at the demonstration site with Ohio River water quality near the Moundsville Grave Creek site and relevant water quality criteria and standards.

7. Environmental Effects. During the proposed v. -k, disturbance of the river bed and bank would result in temporary, construction-related increases in turbidity and suspended matter in the Ohio River downstream of the project site, which would be confined to an approximate 45-day construction period. Grading and recontouring of the bank slope would result in the loss of established herbaceous and woody vegation and exposure of disturbed soil to river currents and weathering. Filter cloth matting would aid in the retention of exposed soil prior to revegetation. The use of air-cooled basic oxygen furnace slag in schemes which specify structural protection may result in a level of water quality degredation commensurate with the bulk chemical content of the slag and the availability of its chemical constituents to the Ohio River as a result of leaching and weathering. However, the quantities of slag involved, weathering and aging of the slag surface and gradual revegetation would tend to minimize the level of chemical constituents leached from the slag. The required excavation would diminish habitat diversity within the riverine littoral region and along the protected shoreline, but would not result in the loss of significantly productive shallow water habitat or aquatic or terrestrial cover necessary to sustain a locally diverse fish or wildlife population.

Both short and long-term benefits would accrue as a result of the proposed action: (1) One or more optimum designs of bank protection would be determined as a result of periodic monitoring and studies of the relative durability of the various demonstration project schemes.

(2) The proposed demonstration project schemes may collectively relieve the acute bank erosion problem at each of the proposed test sites.

B. Demonstration Project.

1. Hydrologic Characteristics. Hydrographs for the demonstration site are shown on Plates 5 and 6. Channel cross-sections are shown on Plate 7. The river channel in the vicinity of the demonstration site has been subject to commercial sand and gravel dredging at various times in the past. Ice formation in the project area becomes significant only during unusually severe winters. Ice movement is not a factor in bank erosion at the site.

2. Hydraulic Characteristics. Velocity distribution measurements were made at the Moundsville demonstration site, 4 miles downstream, and were found to agree with the District computational method within 1/4 foot per second 81 percent of the time. There is some doubt that these distributions apply at the Moundsville, Grave Creek, site because of its location on a bend. Velocity measurements at this site will be made in the future. Average river velocities at the site for given discharges are as follows:

Discharge (cfs)	Frequency of Occurrence (years)	Average Velocity (fps)
20,000		0.8
100,000		3.4
220,000 (1976 flood)		5.2
283,000	10	5.6
348,000 (1972 flood)		5.6
398,000	100	6.5

Piezometers were installed at the demonstration site and monitored twice per week. Plate 8 shows the piezometer locations and Plate 9 shows plots of the piezometric levels and the river stage. Wave action was observed visually under various wind and traffic conditions. The maximum observed wave height was approximately one foot and was induced by traffic during low flow conditions. The minimum pool elevation is maintained at elevation 623 by the operation of Hannibal Locks and Dam, 20 miles downstream. Flows are controlled by eight gated bays, each 110 feet long, and 110-foot long fixed weir section. The dam gates are raised to pass high flows, so that the influence of the dam on the river decreases with increasing flow. At the demonstration site the influence of the dam during floods is insignificant. Prior to the completion of the Hannibal Project in 1975 the river at the demonstration site was maintained at minimum pool elevation 610.5 by Lock and Dam 14. The operation of the wicket type dams is described in paragraph II.A.3.

3. Riverbank Description. The riverbank at the demonstraton site is composed of fine grained alluvium deposited by past flood events in a thinly interbedded structure of fine sands, silts, and clays. Plate 10 shows the logs of the boring made for the installation of piezometers. The landward area is planted with grass and is mowed to within several feet of the top of bank. A few mature trees grow near the top of bank along the demonstration reach.

Erosion at the site is episodic with the majority of bank loss occurring during or immediately following periods of high water. The primary erosion mechanisms at this site are sloughing and piping followed by removal of the disturbed soil by river flows. Sloughing is the stability failure of a block of bank soil that results from saturation during high water and the related pore pressure and weight increase following the subsequent drawdown.

Piping is the development of cavities in the bank face resulting from groundwater seepage concentrating in the more permeable sandy

layers in the bank. The passage of water along these layers tends to remove individual particles of granular material at the face of the bank, in turn removing support for overlying materials.

Erosion at this site has been brought to the attention of the District since at least the early seventies, well before the establishment of the Hannibal pool. Plate 11 shows the condition of the bank prior to the demonstration project.

III. DESIGN AND CONSTRUCTION

A. General. The Moundsville, Grave Creek, site presented the opportunity to evaluate different schemes of bank protection along the outside of a sharp riverbend located with good landward access and where erosion has been a chronic problem. Six schemes were designed to compare varying combinations of structural and vegetal methods of bank protection.

B. Basis for Design. The structural features included a rubber tire wall and a series of variations on the conventional stone bank protection design used by the District at that time. Steel furnace slag was used in lieu of stone because it is an economical, locally available material. The slag is a durable high density by-product of the basic oxygen or electric furnace steel making processes and should not be confused with lighter density blast furnace slag. The slag is graded into various sizes by the suppliers for sale as highway materials, railroad ballast, or fill material. The size range used for bank protection includes a varying percentage of refractory brick from ladle or furnace linings. The refractory material is a durable and angular component of the bank protection. Where a filter was placed between the slag protection and the underlying soil, a woven polypropylene filter fabric was used. The rubber tire wall was constructed with used automobile tires

placed in staggered lifts and filled with gravel. This labor intensive scheme, using a common discarded material, was included in the project because it is feasible for use by small property owners with limited financial resources. The vegetal features included a variety of shrubs, legumes, and grasses planted or seeded in subsections within some schemes of protection. The plants were chosen on the basis of recommendations from other agencies, findings in the literature, and District experience.

C. Construction Details.

1. Scheme 1. This 275-foot reach of protection was constructed by placing graded steel furnace slag along the existing ground surface from pool elevation 623.0 to elevtion 627.0 with a minimum thickness of 18 inches and an outer slope no steeper than one vertical on one horizontal. The slag was well graded between two and 18 inches and was placed without a filter. There was no treatment of the bank above elevation 627.0. Scheme 1 details are shown on Plate 12.

2. Scheme 2. Scheme 2 is a 375-foot long wall constructed of used automobile tires stacked in staggered rows. The succesive rows are placed with a landward offset to provide an overall landward batter to the face of the wall. Each row of tires was filled with gravel prior to placement of the next overlying row. The wall was constructed just riverward of the eroded bank face and the intervening space was filled with sand and gravel placed in lifts concurrent with the rows of tires. The top of the wall rises to elevation 630.0, seven feet above pool, and the bank above the wall was graded to a one on one slope and planted with a variety of shrubs. The wall was founded on a slag fill placed on the existing ground surface to elevation 624.0, one foot above pool. Details of Scheme 2 are shown on Plate 13.

3. Scheme 3. This 250-foot long scheme was constructed by excavating the bank to a one on one slope from elevation 622.0, one foot

below pool, to the top of bank, and placing graded slag from elevation 622.0 to elevation 627.0. The slag was placed atop filter fabric and with an outer slope of one vertical on one and one-half horizontal. The bank above elevation 627.0 was seeded and mulched. Plate 14 shows details of Scheme 3.

4. Scheme 4. This scheme is 350 feet long and comprises a 12-inch thick blanket of graded slag placed atop filter fabric from elevation 623.0 to elevation 630.0 with a variety of shrubs planted on the upper bank slope graded to one vertical on one and one-half horizontal. Scheme 4 details are shown on Plate 15.

5. Scheme 5. This 300-foot long scheme was constructed by grading the bank to a one vertical on two horizontal slope, placing a 12-inch thick blanket of graded slag from elevation 623.0 to elevation 628.0 atop filter fabric, and planting the upper bank with a variety of shrubs. Plate 16 shows details of Scheme 5.

6. Scheme 6. This scheme is 300 feet long and comprised a fill of graded slag with a 2-foot minimum thickness placed from elevation 623.0 to elevation 630.0. The bank was excavated as necessary to achieve the required toe elevation. The outer face of the slag fill was placed to a one vertical on one and one-half horizonal slope. There was no treatment of the bank above elevation 630.0. Details of Scheme 6 are shown on Plate 17.

D. Costs. The Contractor received notice to proceed on 1 December 1977 and all work was completed on 7 June 1978. The final contract cost was $155,534, which included $12,426 in modifications and $12,079 in overruns. The unit prices for the contract included $26 per cubic yard for 1540 cubic yards of slag protection, $5 per square foot for 2772 square feet of rubber tire wall, $21 per cubic yard for 2808 cubic yards of unclassified excavation, $3.50 per square yard for 1730 square yards of filter fabric, $3 per square yard for 357 square yards of seeding and mulching, and $6.50 each for 3265 plants.

The final construction cost per linear foot and per square foot for each scheme was as follows:

SCHEME	COST PER LINEAR FOOT	COST PER SQUARE FOOT
1	$ 19	$ 0.69
2 (structural)	$ 81	$ 8.95
2 (vegetal)	$ 12	$ 1.44
3	$ 57	$ 7.08
4 (structural)	$ 61	$ 3.04
4 (vegetal)	$ 17	$ 1.45
5 (structural)	$ 102	$ 6.37
5 (vegetal)	$ 35	$ 1.95
6	$ 43	$ 3.56

The supervision and inspection cost was $11,340 and the engineering and design cost was $32,000.

IV. PERFORMANCE OF PROTECTION

A. Monitoring Program. The Pittsburgh District Section 32 monitoring program is summarized on Plate 18. Instrumentation at the site comprises three piezometers, installed as shown on Plate 19, and a staff gage. A recording wind measuring station was installed at the Moundsville, W.V. demonstration site located 4 miles downstream. Air temperature and precipitation are measured at the Hannibal and Pike Island navigation projects. The piezometers are read twice weekly and the staff gage is read daily on weekdays by a paid observer. Monitoring inspections by project designers have been made on the average once every two months. These inspections include visual observations and photographs taken from fixed reference points. Overbank cross-sections were surveyed in July 1976, July 1977, May 1978, and April 1981. The site will be resectioned

in April 1983. Soil samples were taken at this site in March 1977 and were tested for gradation, water content, Atterberg limits, and agronomic properties. Quantitative leachate analyses of slag were made on samples taken at potential supply sources in January 1975 and July 1976, and on samples taken from in-place bank protection in August 1978 and February 1980. Annual testing on in-place slag is scheduled through 1983. Controlled vertical low level aerial photography was taken in the spring of 1977, fall of 1978, and spring and fall of 1980. Low angle oblique aerial photography was taken in the fall of 1978 and the spring of 1979. Plates 20 and 21 show vertical aerial photographs of the site taken in September 1978 and March 1980.

B. Evaluation of Protection Performance.

1. General. Erosion at the site has been effectively retarded by the protection schemes, however, some erosion of the upper bank has occurred following episodes of high water. Vandalism of the bank protection has been a factor in performance, particularly at the Scheme 2 rubber tire wall.

2. Scheme 1. The 18-inch thick lower bank slag protection has been effective to the limit of its placement, elevation 627.0. The absence of a filter does not seem to have affected the performance of the slag blanket. There has been some recession of the unprotected bank above elevation 627.0, however, the scarp face seems to be stabilizing with volunteer growth of trees sprouting from exposed roots. The erosion of the upper bank has exposed domestic rubbish, broken bottles, etc, embedded in the bank soil which indicate that the soils being eroded were deposited approximately 50 to 100 years ago. Plates 22 and 23 show photos of Scheme 1.

3. Scheme 2. The wall constructed of used automobile tires has been stable since construction, providing effective protection from erosion. Vandals, however, have achieved what nature could not. On

several occasions since construction segments of the wall, ranging in size from two to twenty tires, have been laboriously dismantled. District employees repaired some early damage, but, the vandalism has outgrown any reasonable hired labor repair effort. Plate 24 shows typical vandalism of the rubber tire wall. The top row of tires was filled with concrete soon after construction to discourage vandals, however, this proved inadequate. At the conclusion of the monitoring period, the District will repair the damages and seek some means to protect the wall from further abuse. The upper bank has stabilized well, even though the plant performance has not been good. The two most successful plants, silky dogwood and arrowood viburnum, are rated in fair condition. The companion grass (tall fescue) seeded among the plants to provide immediate erosion control has been very vigorous and has effectively stabilized the upper bank. The performance of all the vegetal features of the project is summarized on Plate 25. Photos of Scheme 2 are shown on Plates 26, 27 and 28.

4. Scheme 3. The lower bank slag protection has been effective, however, the one on one upper bank slope, above elevation 627.0, is apparently too steep for the seeded grasses to establish. High water has caused some loss of soil and some exposed, oversteepened areas of the slope. Photos of Scheme 3 are shown on Plates 29, 30 and 31.

5. Scheme 4. The blanket of slag protection on the lower bank has effectively prevented erosion, however, some minor displacement has occured as a result of individuals scavenging for scrap steel among the slag. On the upper bank, the most successful plant is the purple osier willow. The companion grass (tall fescue) has been effective in controlling erosion during development of the plants. Plates 32, 33 and 34 show photos of Scheme 4.

6. Scheme 5. This scheme has been effective and, as in Scheme 4, has experienced some slag displacement due to scavenging for scrap. The most successful plant is the red osier dogwood. Photos of Scheme 5 are shown on Plates 35, 36 and 37.

7. Scheme 6. The slag fill placed to elevation 630 has been stable. Minor upper bank recession has occurred, although natural volunteer plant growth has increased since construction. Plates 38 and 39 show photos of Scheme 6.

C. Rehabilitation. Repairs of the Scheme 2 rubber tire wall will be made at the end of the monitoring period. Some method of preventing further vandalism will be sought. Minor additional rehabilitation work on the other schemes may be required depending upon future performance.

D. Summary of Findings.

1. Structural Features. Steel furnace slag, when placed in a 12-inch thickness atop a filter or in an 18-inch thickness without a filter, has been shown to be effective in controlling erosion under the severe hydraulic conditions experienced along the outside of a sharp river bend. Used automobile tires stacked in a staggered arrangement and filled with gravel have resisted erosion, although not vandalism, and have been shown to be an effective means of erosion control well suited to use by an individual property owner with limited financial means.

2. Vegetal Features. Of the various grasses, legumes, and shrubs employed at the site, only three of the shrubs and two of the grasses have shown promise of being effective as erosion control plants in the situations experienced. The most successful shrubs are the purple osier willow (salix purpurea) and red osier dogwood (cornus siricea). Arrowood viburnum (viburnum dentatum) is nearly as effective showing signs of new plants filling in between the original plants. The only grasses that appear effective are the tall fescue (festuca arundinacea) and reed canary grass (phalaris arundinacea).

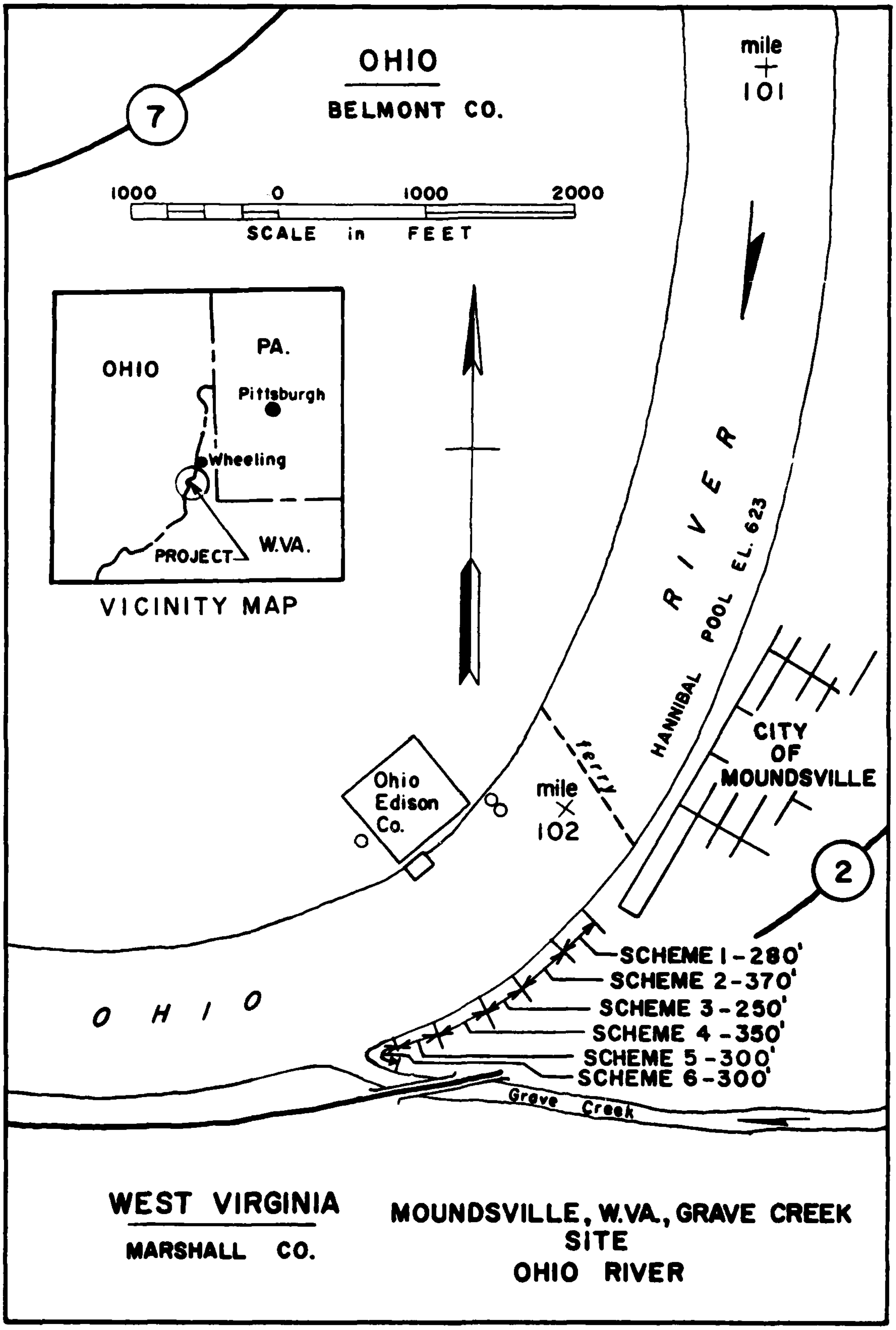
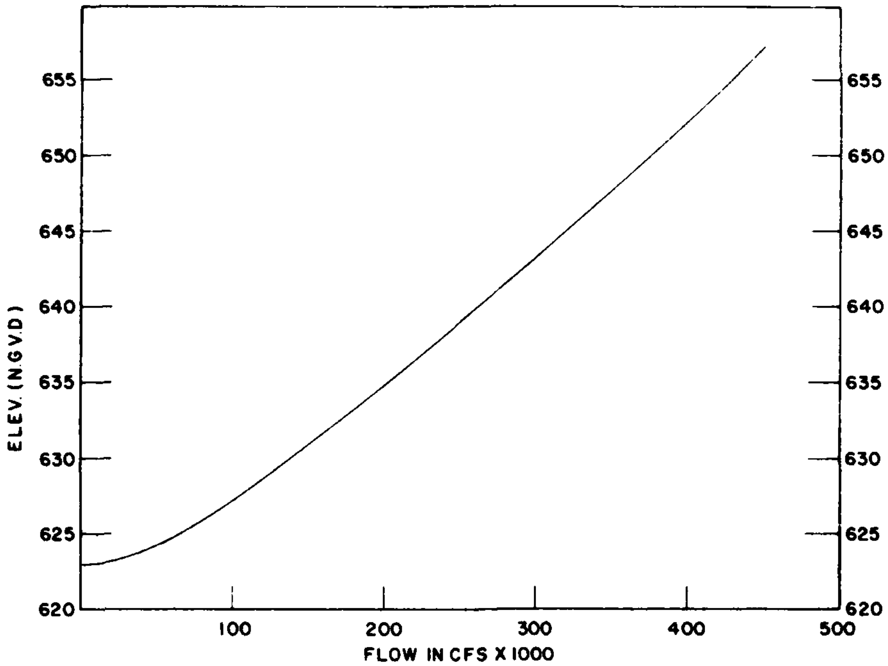
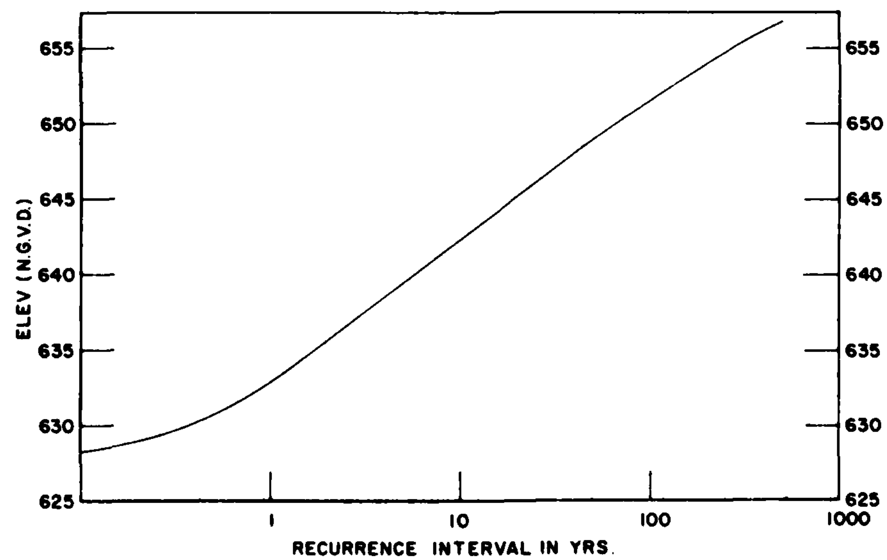

OHIO
BELMONT CO.
7
mile
101
1000
0
1000
2000
SCALE in FEET
OHIO
PA.
Pittsburgh
Wheeling
PROJECT
W.VA.
VICINITY MAP
RIVER
HANNIBAL POOL EL. 623
CITY OF MOUNDSVILLE
ferry
mile
102
Ohio Edison Co.
2
SCHEME 1 - 280'
SCHEME 2 - 370'
SCHEME 3 - 250'
SCHEME 4 - 350'
SCHEME 5 - 300'
SCHEME 6 - 300'
OHIO
Grave Creek
WEST VIRGINIA
MARSHALL CO.
MOUNDSVILLE, W.VA., GRAVE CREEK SITE
OHIO RIVER

PLATE 1



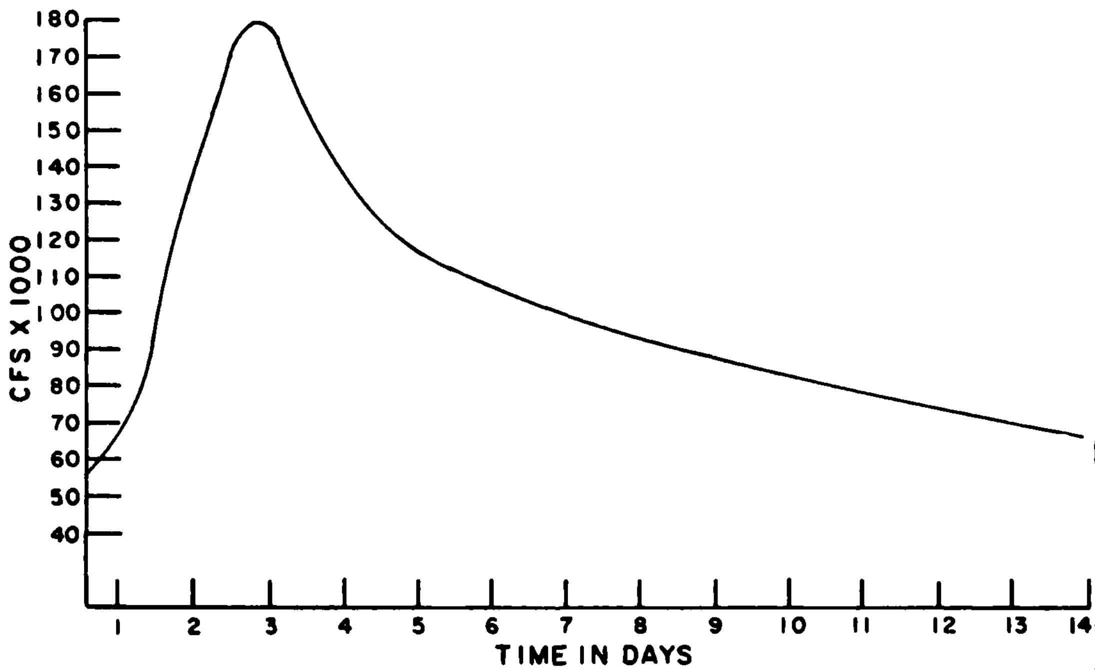
DISCHARGE RATING CURVE MI. 102.36



STAGE FREQUENCY CURVE MI. 102.36

MOUNDSVILLE, W. VA. GRAVE CREEK
SITE
OHIO RIVER

PLATE 2



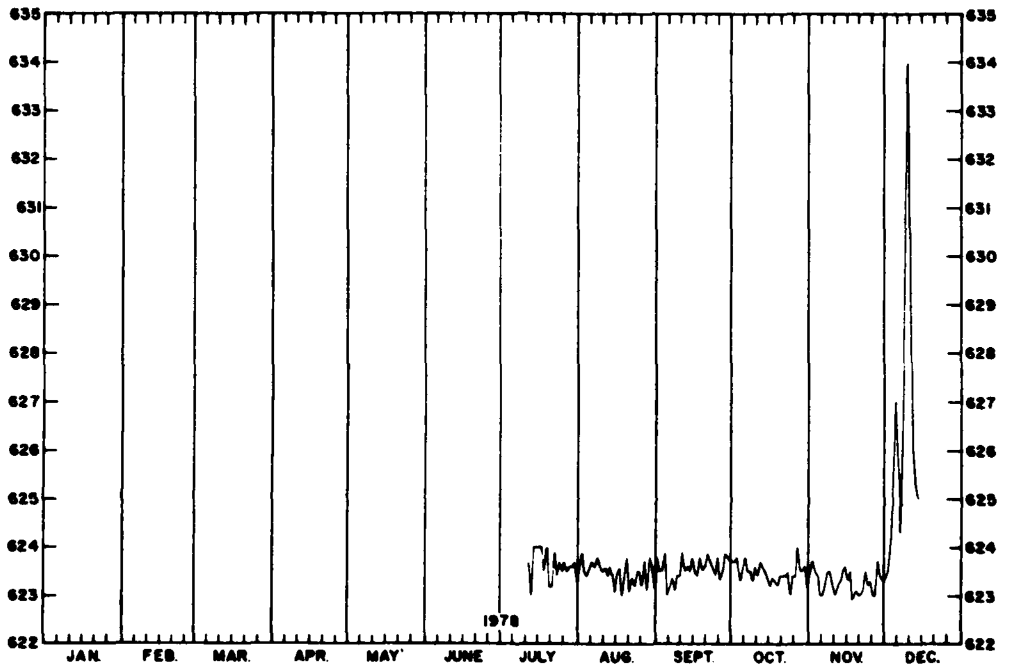
ONE YEAR FLOOD HYDROGRAPH
MOUNDSVILLE, W. VA. GRAVE CREEK
SITE
OHIO RIVER

PLATE 3

PARAMETER mg/l	SLAG IN RIVER WATER	SLAG IN D.I. WATER	RIVER WATER	W. VA. CRITERIA 1980	EPA CRITERIA 1972
Alkalinity M.O.	64	78	37		
Arsenic (As)	< 0.005	<0.005	< 0.005	0.05	0.01
Barium (Ba)	< 0.1	<0.1	< 0.1	1.0	1.0
Cadmium (Cd)	< 0.01	<0.01	< 0.01	0.01	0.01
Chloride (Cl)	28	22	24	250	250
Chromium (Cr^{+6})	0.004	0.004	< 0.002	0.05	0.05
Chromium Total	< 0.02	<0.03	< 0.03		
Color (APHA)	5-10	0-5	30-40		75
Copper (Cu)	< 0.02	<0.02	< 0.02	0.005	1.0
Cyanide Total (Cn)	0.006	0.003	0.018	0.025	0.2
Fluoride (F)	0.67	0.52	0.23	1.0	
Hardness ($CaCO_3$)	168	82	122		
Iron Total (Fe)	0.37	0.07	5.6	1.0	0.3
Lead (Pb)	< 0.05	<0.05	< 0.05	0.05	0.05
Magnesium (Mg)	11	0.93	9.4		
Manganese (Mn)	0.04	<0.02	0.54	0.05	0.05
Mercury (Hg) ug/l	< 0.02	<0.2	< 0.2	0.2	2.0
Nitrate (N)	2.0	<0.2	1.1	10.0	10.0
PH	7.0	7.9	7.4	6.0-9.0	5.0-9.0
Phenol	0.004	0.002	0.003	0.005	0.001
Selenium (Se)	< 0.005	<0.005	< 0.005	0.005	0.01
Silver (Ag)	< 0.02	<0.02	< 0.02	0.05	
Solids Dissolved	328	100	246		
Solids Suspended	2	1	120		
Solids Total	341	125	366		
Sulfate (SO_4)	120	<2.5	97		250
Sulfide (S)	< 0.02	<0.2	<0.02		
Zinc (Zn)	< 0.02	<0.2	<0.25	0.05	5.0

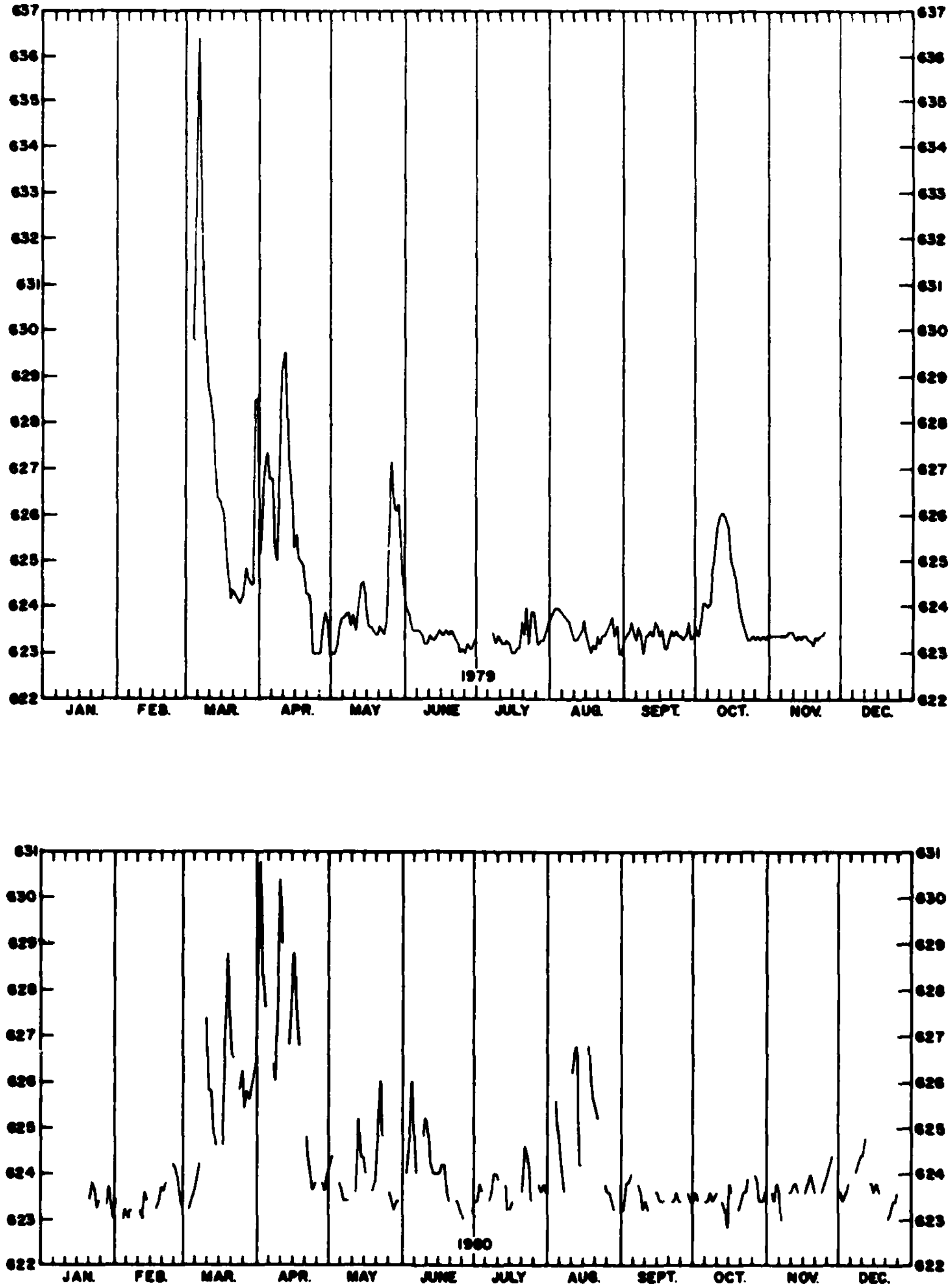
SLAG LEACHATE COMPARISON
MOUNDSVILLE, W. VA., GRAVE CREEK
SITE
OHIO RIVER

PLATE 4



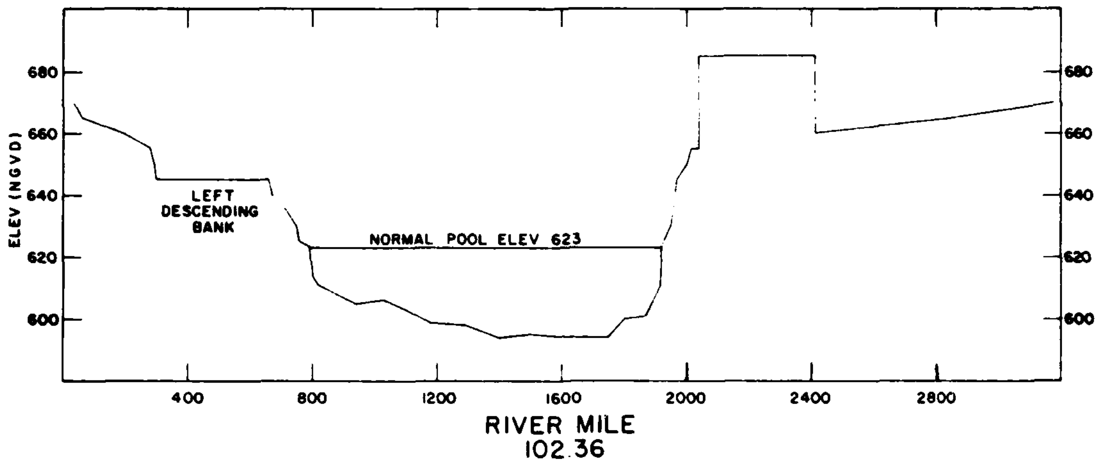
HYDROGRAPH
MOUNDSVILLE, W. VA, GRAVE CREEK SITE
OHIO RIVER

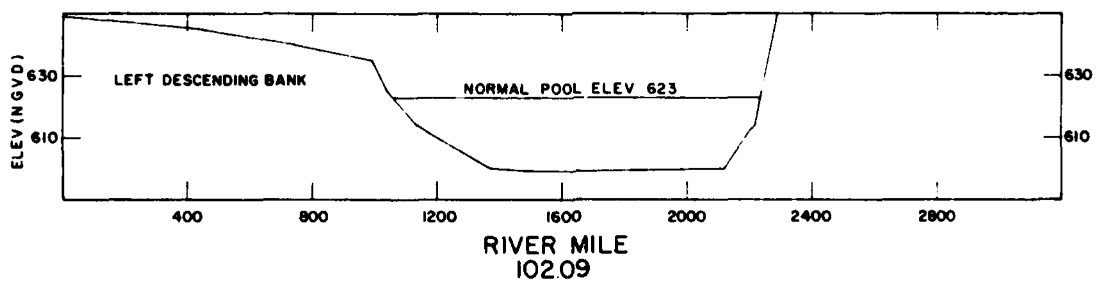
PLATE 5



HYDROGRAPHS
MOUNDSVILLE, W. VA, GRAVE CREEK
SITE
OHIO RIVER

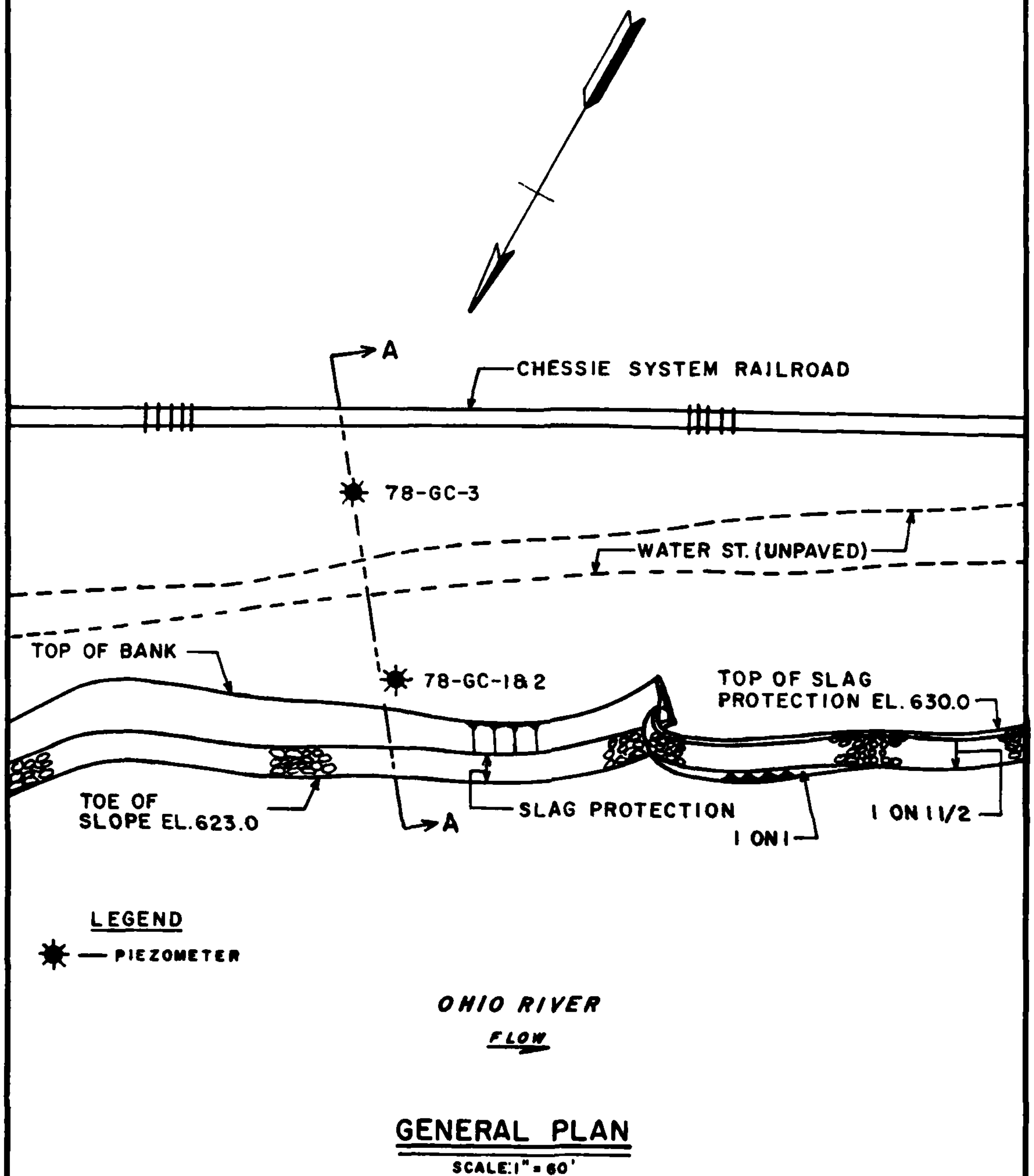
PLATE 6





CHANNEL CROSS SECTIONS
MOUNDSVILLE, W. VA., GRAVE CREEK
SITE
OHIO RIVER

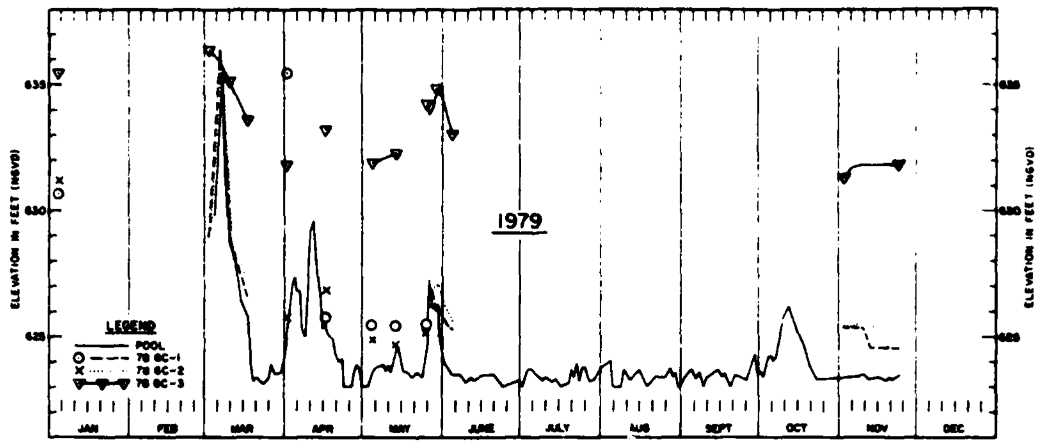
PLATE 7

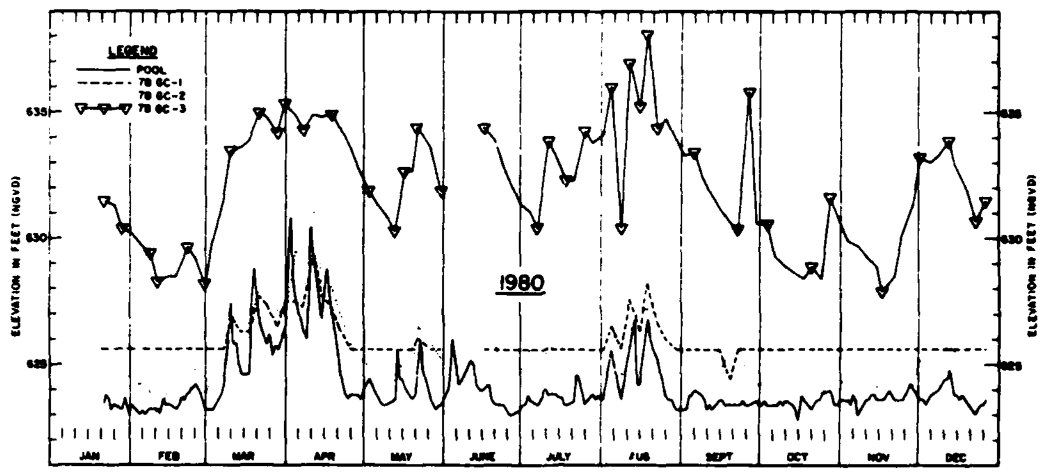


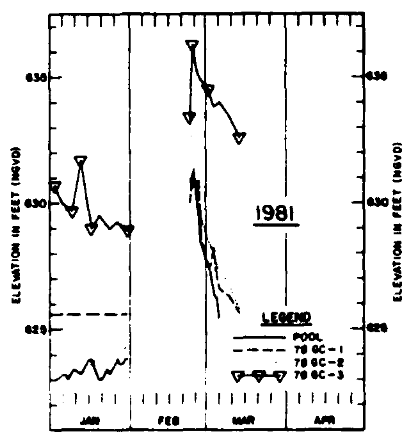
GENERAL PLAN
SCALE: 1" = 60'

PIEZOMETER LOCATIONS
MOUNDSVILLE, W. VA., GRAVE CREEK
SITE
OHIO RIVER

PLATE 8







PIEZOMETER PLOTS
MOUNDSVILLE, W. VA.
GRAVE CREEK SITE
OHIO RIVER

PLATE 9

LOCATION	DIRECTION OF HOLE FROM VERTICAL	DATE HOLE	HOLE NO.	SIZE AND TYPE OF BIT OR SAMPLER
STA 20+50 60 Feet Right	0°	Started 3 OCT 1978 Completed 4 OCT 1978	78-GC-1 & 2	Roller Bit 2 in O.D. Split Spoon 140lb Hammer - 30 in Drop

ELEVATION	DEPTH	LL	PL	W%	BLOWS PER 0.5 FEET	LEGEND	CLASSIFICATION OF MATERIALS (Description)	BOX OR SAMPLE NO.	EST. GRADATION % GRAVEL	SAND	FINES	REMARKS
635.8	G.0				3-6 7-CO		Silty CLAY, brown	1				TOP OF ROCK
633.8	2.0				1-2 2-CO		Sandy clayey SILT br, sand fine	2				
631.8	4.0				1-1 2-CO		same	3				
629.8	6.0			30.4	1-1 4-CO	ML	Sandy SILT, br, w tr clay tr rootlets, wood	4	* 0	24	76	
627.8	8.0				1-2 4-CO		Silty SAND, brown w tr clay	5				
1 → 625.8 625.6	10.0 10.2	33.5	10.6	23.0	3-6 7-CO	CL	Sandy silty CLAY, brown	6	* 0	16	84	
623.8	12.0				3-5 8-CO		NO RECOVERY	7				
621.8	14.0				3-6 8-CO		Silty sandy CLAY, brown	8				
619.8	16.0				2-6 7-CO		same	9				
617.8 2 → 617.5	18.0 18.3				3-8 9-CO	CL	Sandy silty CLAY, brown, sand fine	10	* 0	13	87	
615.8	20.0				3-4 5-CO		Silty CLAY, mottled brown and gray	11				
613.8	22.0				2-4 4-CO		same	12				
611.8	24.0				2-5 5-CO		Silty CLAY, gray	13				
609.8	26.0				2-5 7-CO		same	14				
607.8	28.0				3-4 8-CO		same	15				
605.8	30.0				3-4 5-CO		same	16				
603.8	32.0				3-5 11-CO		Silty CLAY, gray Silty SAND, gray, w SS frags	17				
601.8	34.0				3-5 7-CO		Silty CLAY gr, w few small gravels	18				
599.8	36.0				3-6 10-CO		Silty CLAY, gr, few gravels & SS frags	19				
597.8	38.0				3-7 9-CO		SANDSTONE FRAGMENTS	20				
595.8 594.8	40.0 41.0				10-75/0.5 CO		SHALE, brown, badly weathered	21				TOP OF ROCK
593.8 593.1	42.0 42.7				[illegible]		SHALE, gray, badly weathered	22				BOTTOM OF HOLE

LOCATION	DIRECTION OF HOLE FROM VERTICAL	DATE HOLE	HOLE NO.	SIZE AND TYPE OF BIT OR SAMPLER
STA 20+50 12 Feet Left	0°	Started 5 OCT 1978 Completed 5 OCT 1978	78-GC-3	Roller Bit 2 in O.D. Split Spoon 140lb Hammer - 30 in Drop

ELEVATION	DEPTH	LL	PL	W%	BLOWS PER 0.5 FEET	LEGEND	CLASSIFICATION OF MATERIALS (Description)	BOX OR SAMPLE NO.	EST. GRADATION % GRAVEL	SAND	FINES	REMARKS
644.9	0.0				9-14 10-CO		SILT and SLAG, brown	1				TOP OF ROCK
642.9	2.0				2-1 1-CO		SLAG	2				
640.9	4.0				2-1 1-CO	/	same	3				
638.9	6.0				2-2 3-CO		same	4				
636.9	8.0				2-3 5-CO		Sandy silty CLAY, brown, sand fine	5				
634.9	10.0			25.7	4-7 8-CO	ML	Silty CLAY, br, w/tr fine sand	6	* 0	7	93	
632.9	12.0				5-7 12-CO		same	7				
630.9	14.0				5-8 3-CO		same	8				
628.9	16.0				5-8 14-CO		same	9				
626.9	18.0				5-6 11-CO		same	10				
624.9	20.0				5-8 12-CO		same	11				
622.9	22.0				4-6 9-CO		same	12				
620.9 3 → 619.9 618.9	24.0 25.0 26.0			25.9	NOT RECORDED	CL	Sandy silty CLAY, brown, sand fine	13	* 0	12	88	BOTTOM OF HOLE

LEGEND

——● - INDICATES PIEZOMETER TIP ELEVATION
CLAY - FIELD CLASSIFICATION
CLAY - LABORATORY CLASSIFICATION
* - ACTUAL GRADATION

GEOLOGIC ABBREVIATIONS

ANG - ANGULAR
FRAGS - FRAGMENTS
USC - UNIFIED SOILS CLASSIFICATION
CO - CLEAN OUT
D - DRILLED
EST. - ESTIMATED
W - WITH
br - BROWN
gr - GRAY
tr - TRACE

STANDARD ABBREVIATIONS USED

W% - WATER CONTENT
PL - PLASTIC LIMIT
LL - LIQUID LIMIT
F/W - FREE WATER
G.W. - GROUND WATER
MP - MEDIUM PLASTICITY
LP - LOW PLASTICITY
MHP - MEDIUM HIGH PLASTICITY
NP - NON-PLASTIC

PIEZOMETER BORING LOGS
MOUNDSVILLE, W. VA., GRAVE CREEK SITE
OHIO RIVER

PLATE 10

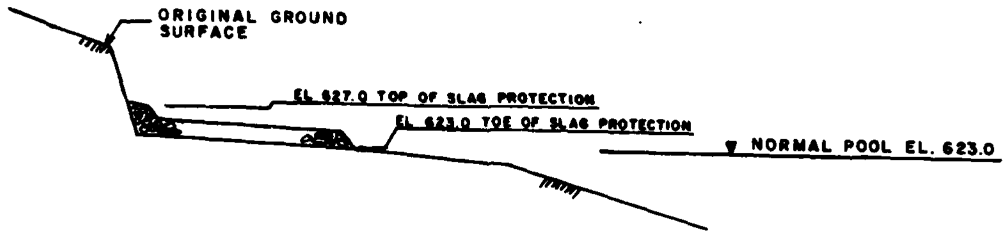
4 SEPTEMBER 1975

25 MARCH 1977

13 DECEMBER 1977

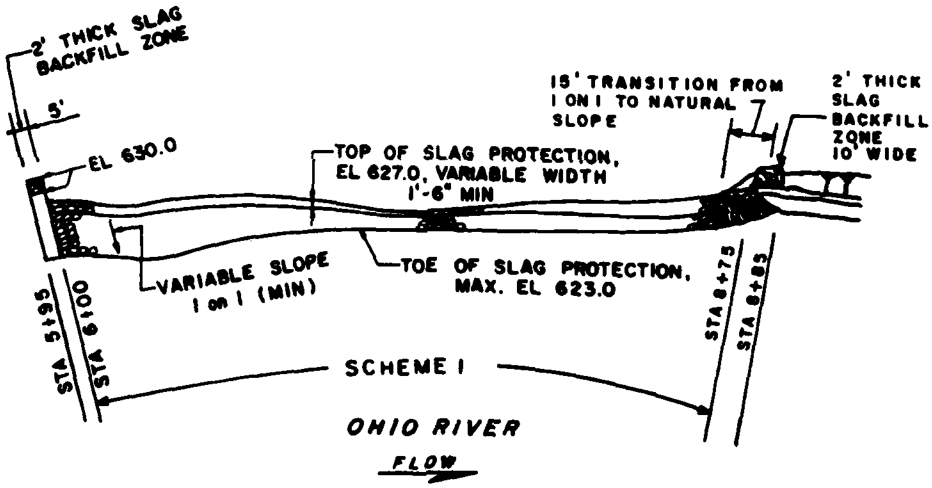
SITE PHOTOS
MOUNDSVILLE, W. VA. GRAVE CREEK
SITE
OHIO RIVER

PLATE 11



SCHEME I

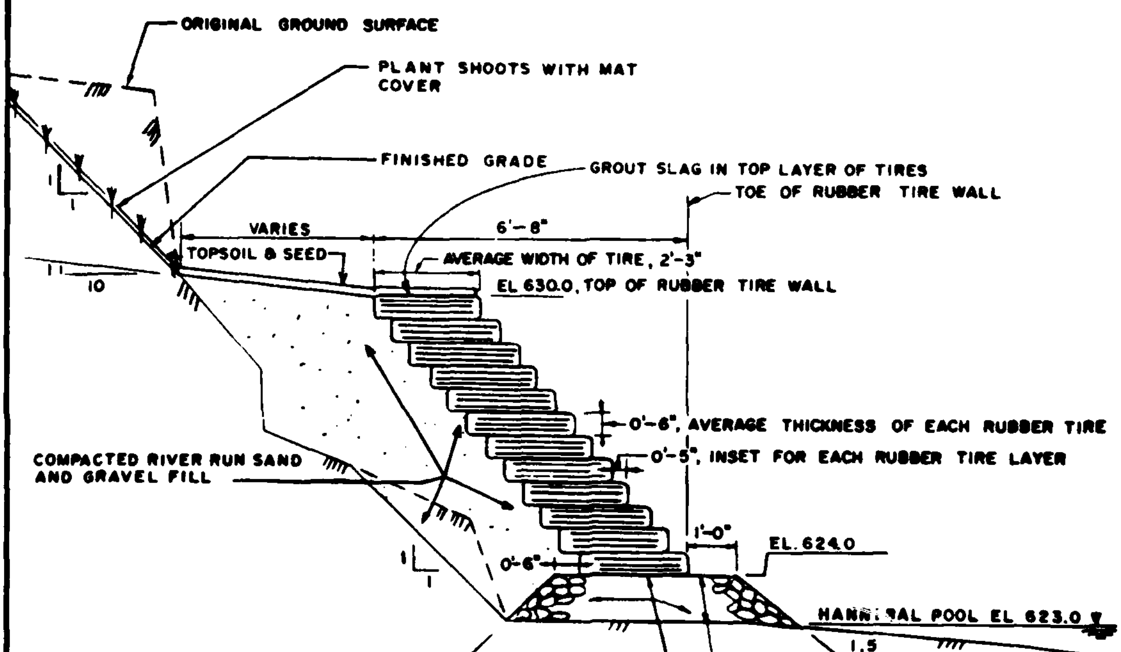
STA. 6+00 TO STA. 8+75
NOT TO SCALE



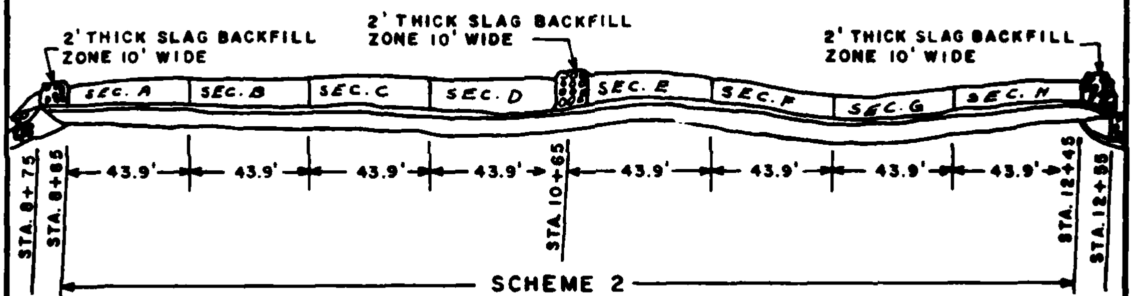
NOT TO SCALE

SCHEME I
MOUNDSVILLE, W. VA., GRAVE CREEK
SITE
OHIO RIVER

PLATE 12



SCHEME 2
STA.8+85 TO STA.12+45
NOT TO SCALE



OHIO RIVER FLOW

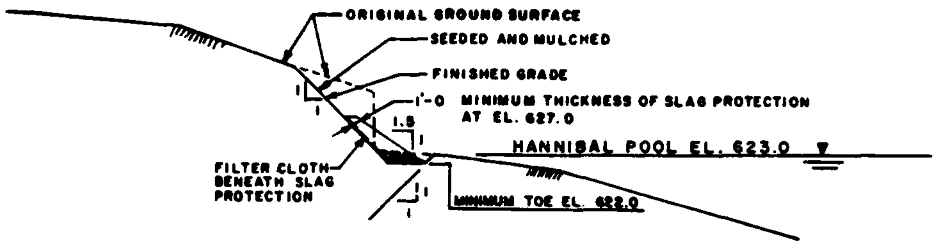
NOT TO SCALE

PLANT LIST

SECTION BOTANICAL NAME	COMMON NAME
SHRUBS	
A. SALIX PURPUREA	PURPLE OSIER WILLOW
B. CORNUS AMOMUM	SILKY DOGWOOD
C. CORNUS SIRICEA	RED OSIER DOGWOOD
D. MYRICA PENSYLVANICA	NORTHERN BAYBERRY
E. VACCINIUM ANGUSTIFOLIUM	LOWBUSH BLUEBERRY
F. VIBURNUM DENTATUM	ARROWWOOD VIBURNUM
G. ALNUS RUGOSA	SPECKLED ALDER
H. SPIREA SALICIFOLIA	WILLOW SPIREA

SCHEME 2
MOUNDSVILLE, W.VA., GRAVE CREEK SITE
OHIO RIVER

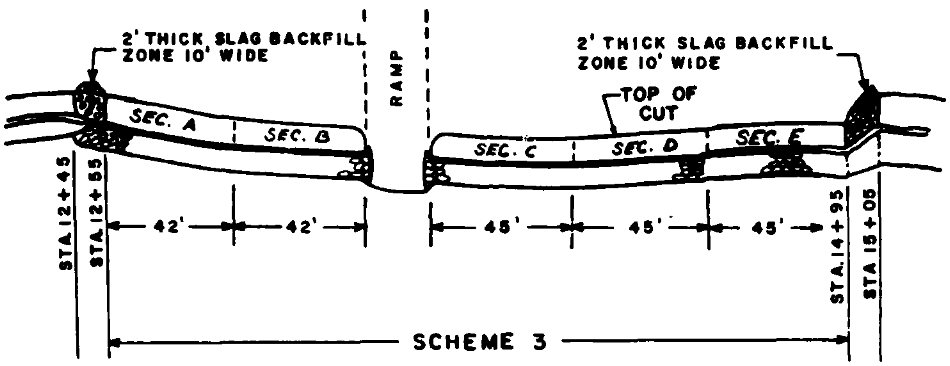
PLATE 13



SCHEME 3

STA. 12+55 TO STA. 14+95

NOT TO SCALE



OHIO RIVER

FLOW

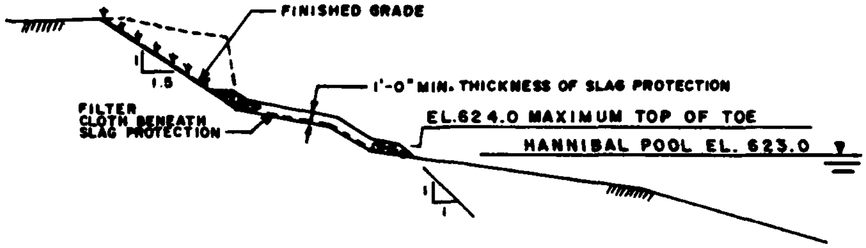
NOT TO SCALE

PLANT LIST

SECTION	BOTANICAL NAME	COMMON NAME	LBS OF SEED / ACRE
	LEGUMES & GRASSES		
A	PHALARIS ARUNDINACEA	REED CANARYGRASS	25
	AGROSTIS ALBA	REDTOP	5
	LOTUS CORNICULATUS	BIRDSFOOT TREFOIL	10
B	FESTUCA ARUNDINACEA	TALL FESCUE (KY. 31 ALTA)	30
	AGROSTIS ALBA	REDTOP	5
	LOTUS CORNICULATUS	BIRDSFOOT TREFOIL	10
C	FESTUCA ARUNDINACEA	TALL FESCUE (KY. 31 ALTA)	30
	CORONILLA VARIA "PENNGIFT"	CROWN VETCH	10
D	FESTUCA ARUNDINACEA	TALL FESCUE (KY 31 ALTA)	35
	AGROSTIS ALBA	REDTOP	5
E	LESPEDEZA CUNEATA	LESPEDEZA SERICA	10
	PHALARIS ARUNDINACEA	REED CANARYGRASS	15

SCHEME 3
MOUNDSVILLE, W. VA., GRAVE CREEK SITE
OHIO RIVER

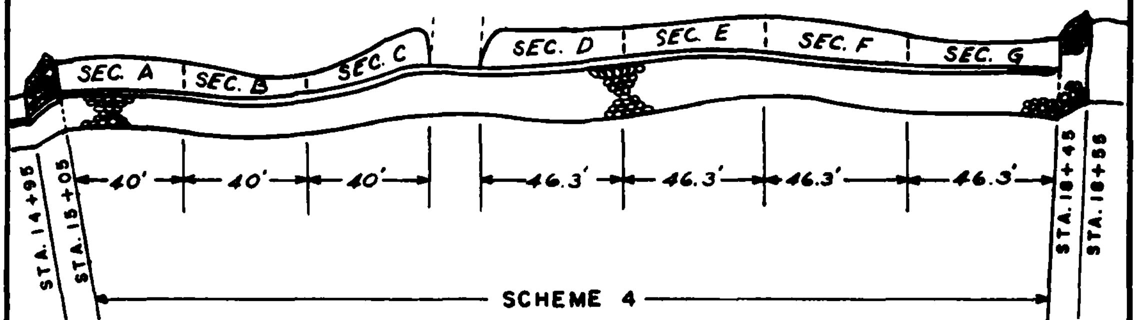
PLATE 14



SCHEME 4

STA.15+05 TO STA.18+45

NOT TO SCALE



OHIO RIVER

FLOW

NOT TO SCALE

PLANT LIST

SECTION BOTANICAL NAME	COMMON NAME
SHRUBS	
A. SALIX PURPUREA	PURPLE OSIER WILLOW
B. CORNUS AMOMUM	SILKY DOGWOOD
C. CORNUS SIRICEA	RED OSIER DOGWOOD
D. MYRICA PENSYLVANICA	NORTHERN BAYBERRY
E VACCINIUM ANGUSTIFOLIUM	LOWBUSH BLUEBERRY
F VIBURNUM DENTATUM	ARROWWOOD VIBURNUM
G. ALNUS RUGOSA	SPECKLED ALDER

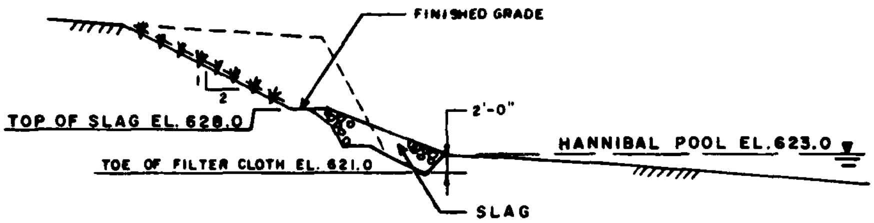
SCHEME 4

MOUNDSVILLE, W. VA., GRAVE CREEK

SITE

OHIO RIVER

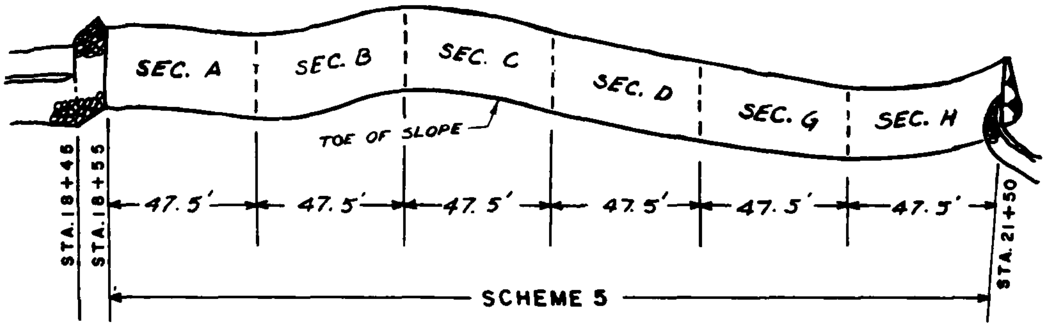
PLATE 15



SCHEME 5

STA 18+55 TO STA. 21+50

NOT TO SCALE



OHIO RIVER

FLOW

NOT TO SCALE

PLANT LIST

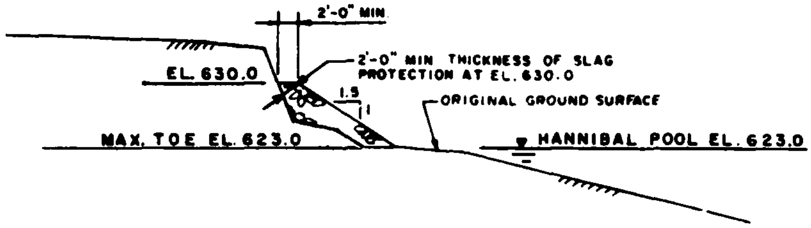
SECTION	BOTANICAL NAME	COMMON NAME
	SHRUBS	
A	SALIX PURPUREA	PURPLE OSIER WILLOW
B	CORNUS AMOMUM	SILKY DOGWOOD
C	CORNUS SIRICEA	RED OSIER DOGWOOD
D	MYRICA PENSYLVANICA	NORTHERN BAYBERRY
G	ALNUS RUGOSA	SPECKLED ALDER
H	SPIREA SALICIFOLIA	WILLOW SPIREA

SCHEME 5

MOUNDSVILLE, W. VA., GRAVE CREEK SITE

OHIO RIVER

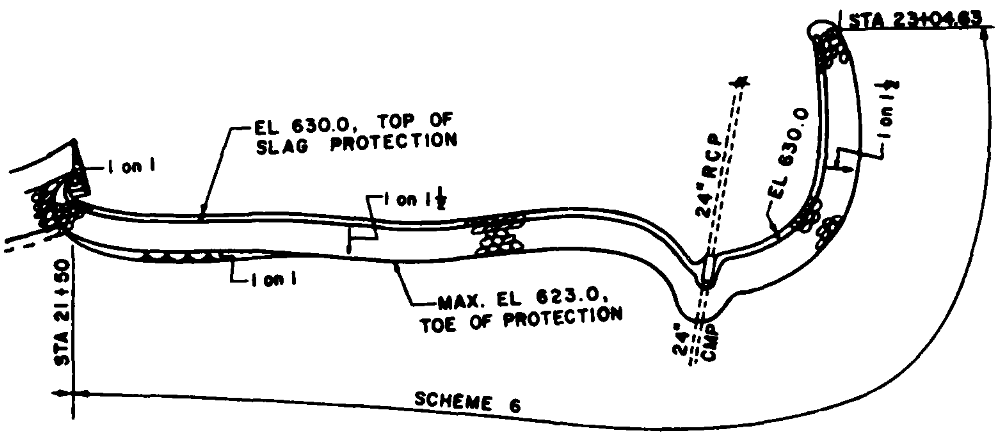
PLATE 16



SCHEME 6

STA. 21+50 TO STA. 23+04.63

NOT TO SCALE



OHIO RIVER

FLOW

NOT TO SCALE

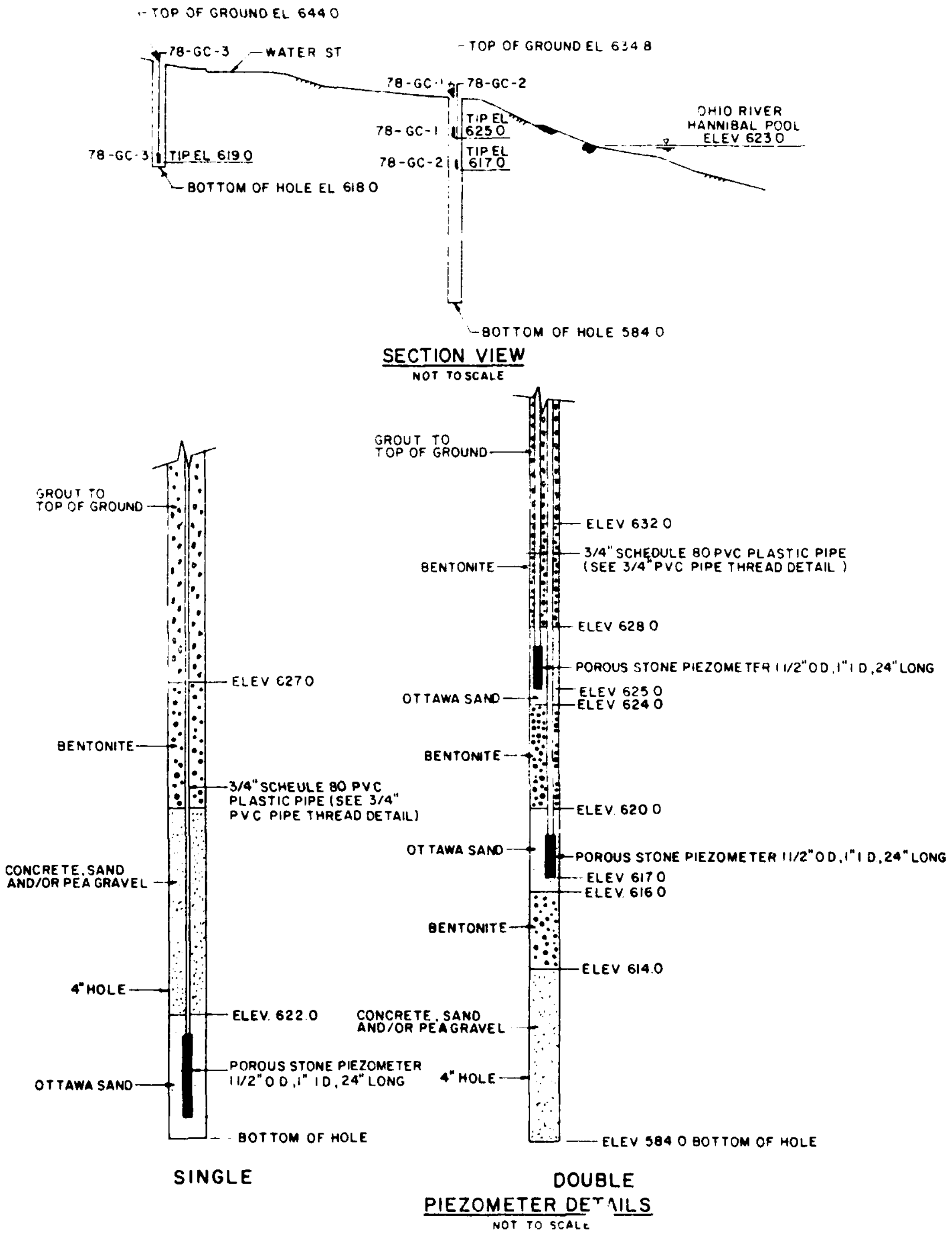
SCHEME 6
MOUNDSVILLE, W. VA., GRAVE CREEK
SITE
OHIO RIVER

PLATE 17

PARAMETER	ITEM	FREQUENCY
GEOMETRY	1. Cverbank crossections from baseline to 50 ft. riverward of water's edge at 50 ft. intervals	Biyearly
	2. Full channel crossections	Once
	3. Ground photos from fixed reference points	Monthly
	4. Controlled vertical low level aerial photos	Annual
CLIMATE	1. Air temp., precip., wind direction and velocity (recorded at Moundsville, WV site)	Continuous
	2. Ice conditions, snow cover noted from visual observations	As available
HYDRAULICS	1. River stage record from staff gage near sta. 14+50	Twice daily by observer
	2. River traffic (through observation and lock records)	As available
STREAM-BANK PROTECTION	1. Monitor dimensional changes of marked structural & vegetal through photos and manual measurement	Monthly
	2. Observe durability of marked units of structural material (qualitative)	Monthly
	3. Observe condition of marked plants	Monthly
	4. Record initiation and measure progression of failures in bank protection	Monthly
GEOLOGY AND SOILS	1. Material properties testing	Annual
	2. Cbservation of groundwater level piezometers (3)	Semi-weekly

MONITORING PROGRAM
MOUNDSVILLE, W. VA., GRAVE CREEK SITE
OHIO RIVER

PLATE 18



PIEZOMETER INSTALLATION
MOUNDSVILLE, W. VA., GRAVE CREEK SITE
OHIO RIVER

PLATE 19

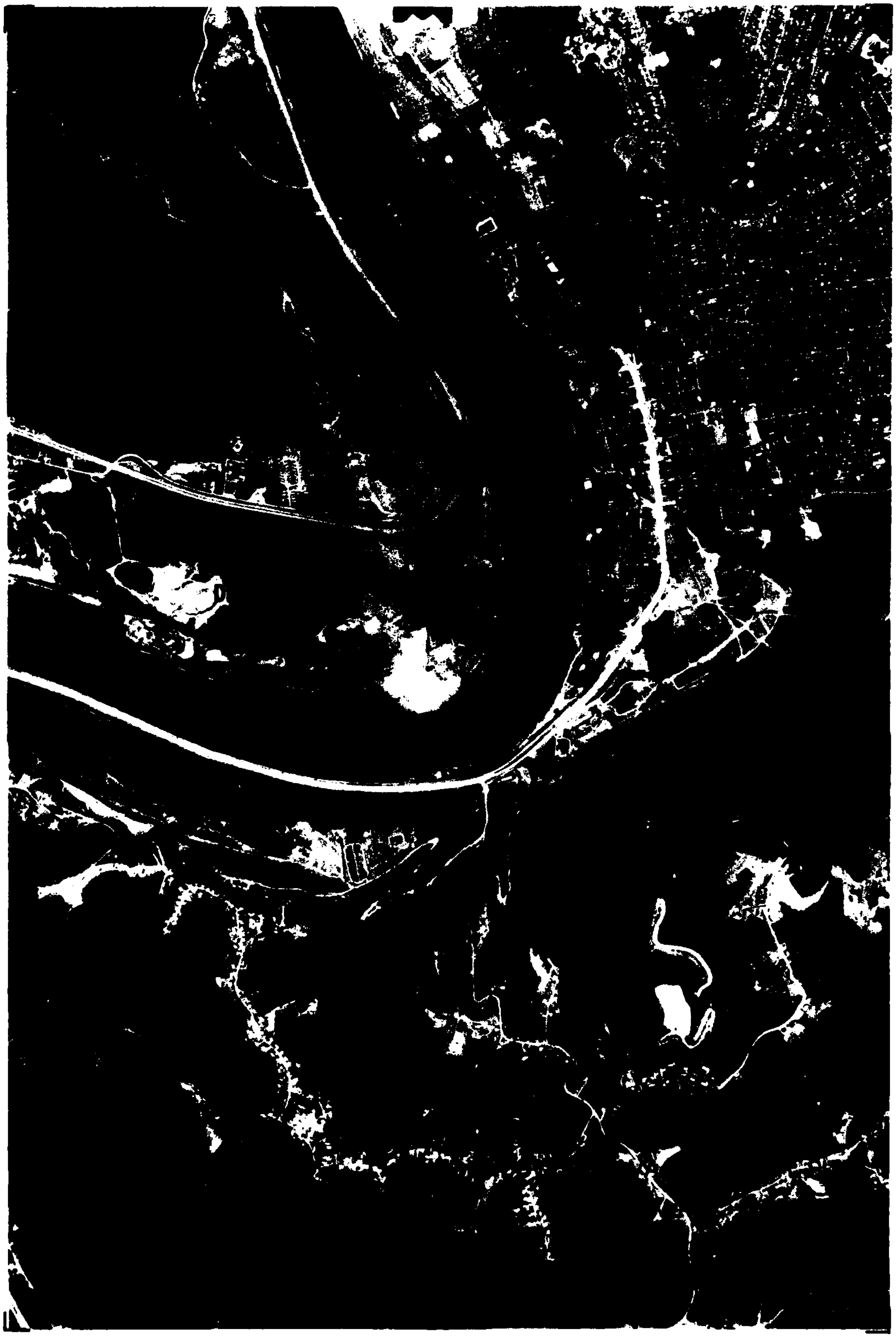


PLATE 20

PLATE 20

PLATE 21

FROM STATION 6+00
12 MAY 1978

FROM STATION 6+00
24 OCTOBER 1978

FROM STATION 6+00
26 APRIL 1979

SCHEME 1 PHOTOS
MOUNDSVILLE, W.VA. GRAVE CREEK
SITE
OHIO RIVER

PLATE 22

FROM STATION 6+00
25 OCTOBER 1979

FROM STATION 6+00
8 APRIL 1980

FROM STATION 6+00
3 DECEMBER 1980

SCHEME 1 PHOTOS
MOUNDSVILLE, W.VA. GRAVE CREEK
SITE
OHIO RIVER

PLATE 23

26 APRIL 1979

3 DECEMBER 1980

3 DECEMBER 1980

SCHEME 2 TIRE WALL DAMAGE
MOUNDSVILLE, W.VA. GRAVE CREEK
SITE
OHIO RIVER

PLATE 24

SCHEME (1)	SECTION (2)	INITIAL SPACING (3)	% OF PLANTED SECTION GROWING (4)	(PER SQ FT) DENSITY INCREASE OR DECREASE (5)	CONDITION OF PLANTS (6)	COMPARATIVE VALUE (7)	DATE PLANTED MAY 78 / CURRENT DATE MAY 80 — REMARKS (8, 9)
2	A	2'X2' O.C.	20	DECREASE	GOOD	120	Seeded grass,(KY-31),is much
	B	2'X2' O.C.	60	DECREASE	FAIR	135	more vigorus than test plants
	C	2'X2' O.C.	40	DECREASE	POOR	90	Same
	D	2'X2' O.C.	10	DECREASE	FAIR	85	Same
	E	2'X2' O.C.	5	—	—	5	Same
	F	2'X2' O.C.	80	SAME	FAIR	180	Same
	G	2'X2' O.C.	5	DECREASE	—	30	Replaced with Silky Dogwood
	H	2'X2' O.C.	5	DECREASE	POOR	80	Replaced with Red Osier Dogwood
3	A	3 PLANT MIX	a 75 b 0 c 5	DECREASE	GOOD	180	a. CANARYGRASS DOING WELL b.[illegible] VERY POOR OR NON-EXISTANT
	B	3 PLANT MIX	a 65 b 25 c 10	SAME	GOOD	225	a. FESCUE (KY-31) DOING WELL b.c. POOR - FAIR
	C	2 PLANT MIX	50	DECREASE	FAIR	125	STEEP BANK BARE SPOTS; EXPOSED SOIL
	D	2 PLANT MIX	10	DECREASE	POOR	60	Same
	E	2 PLANT MIX	50	DECREASE	GOOD	150	No Lespedeza
4	A	2'X2' O.C.	90	INCREASE	EX.	265	
	B	2'X2' O.C.	60	DECREASE	FAIR	135	Replaced with Viburnum-2'to3' tall
	C	2'X2' O.C.	90	SAME	GOOD	215	KY-31 Grass good
	D	2'X2' O.C.	—	—	—	—	Replanted w/Red Osier 2'to3' tall 70%
	E	2'X2' O.C.	—	—	—	—	" " V. Dentatum 1'to2' tall 50%
	F	2'X2' O.C.	80	SAME	GOOD	205	
	G	2'X2' O.C.	50	DECREASE	FAIR	125	
5	A	2'X2' O.C.	40	DECREASE	GOOD	140	
	B	2'X2' O.C.	5	DECREASE	POOR	55	Seeded companion grass,(KY-31),
	C	2'X2' O.C.	90	INCREASE	GOOD	240	is very vigorous.
	D	2'X2' O.C.	5	DECREASE	FAIR	80	Same
	G	2'X2' O.C.	50	DECREASE	FAIR	125	Same
	H	2'X2' O.C.	40	DECREASE	FAIR	115	Same

COMPARATIVE VALUE RATIONALE. IN ORDER TO GIVE EACH PLANTED SECTION A VALUE TO INDICATE THE DEGREE OF PLANT SUCCESS, THE VALUES LISTED IN COLUMNS 4,5 & 6 ARE COMBINED TO FORM A TOTAL COMPARATIVE VALUE AS SHOWN IN COLUMN 7. A COMPARATIVE VALUE OF 300 IS MAXIMUM. A VALUE OF 0 IS MINIMUM, INDICATING PLANT FAILURE IN ALL CATEGORIES.

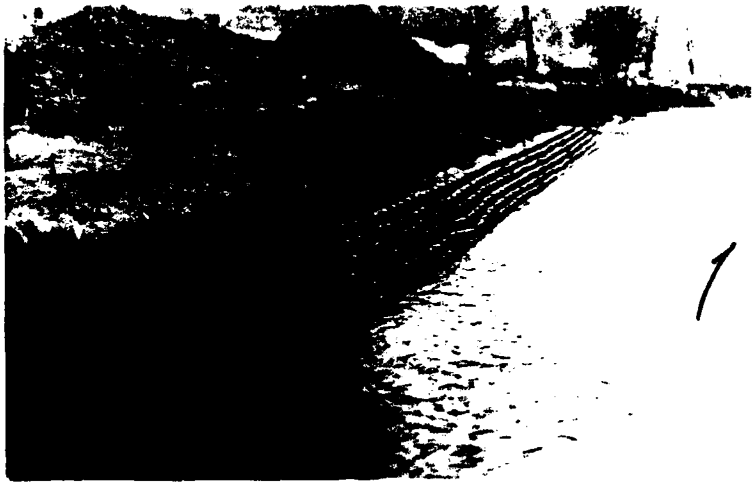
THE VALUE OF COLUMN 4 IS EQUAL TO THE PERCENT SHOWN, AND REPRESENTS THE PERCENT OF THE SECTION COVERED BY PLANTS.

COLUMN 5 VALUES:
- EXCEPTIONAL INCREASE OR VERY GOOD GERMINATION — 100
- INCREASE OR GOOD GERMINATION — 75
- SAME OR POOR GERMINATION — 50
- DECREASE OR VERY POOR GERMINATION — 25
- BLANK SPACE OR 0 — 0

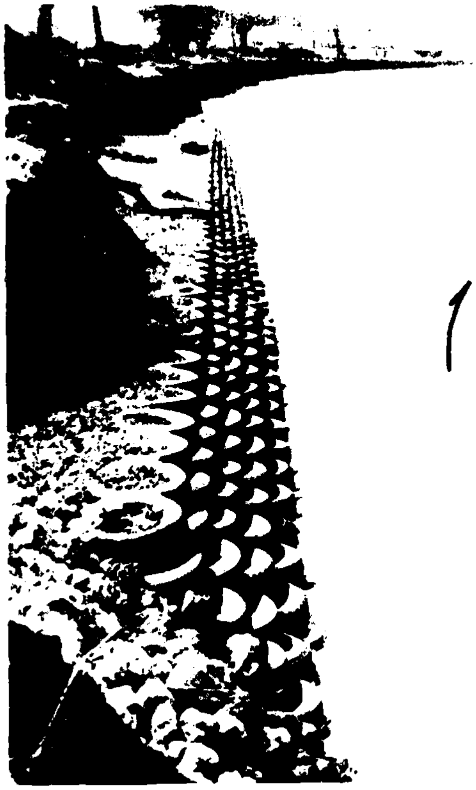
COLUMN 6 VALUES:
- EX (EXCELLENT) — 100
- GOOD — 75
- FAIR — 50
- POOR — 25
- BLANK SPACE OR 0 — 0

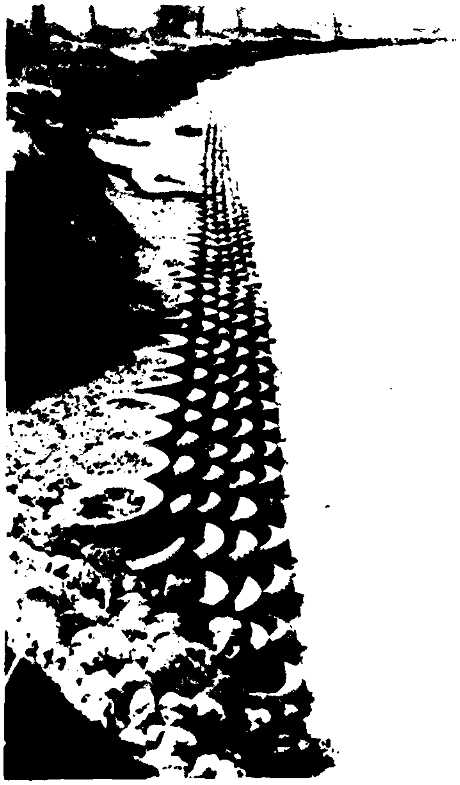
PLANT MATERIAL EVALUATION
MOUNDSVILLE, W. VA., GRAVE CREEK SITE
OHIO RIVER

PLATE 25



DURING CONSTRUCTION
TAKEN FROM STATION
8+75
16 MARCH 1978





STEREOSCOPIC VIEW TAKEN FROM
STATION 8+80 DURING CONSTRUCTION
29 MARCH 1978

SCHEME 2 PHOTOS
MOUNDSVILLE, W.VA. GRAVE CREEK
SITE
OHIO RIVER

PLATE 26

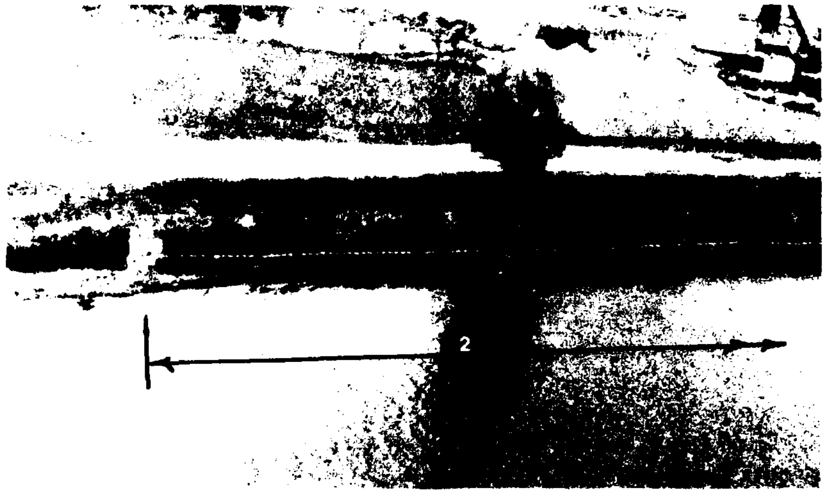
FROM STATION 8+80
27 JUNE 1978

FROM STATION 8+80
21 DECEMBER 1978

FROM STATION 8+80
26 APRIL 1979

SCHEME 2 PHOTOS
MOUNDSVILLE, W.VA. GRAVE CREEK
SITE
OHIO RIVER

PLATE 27



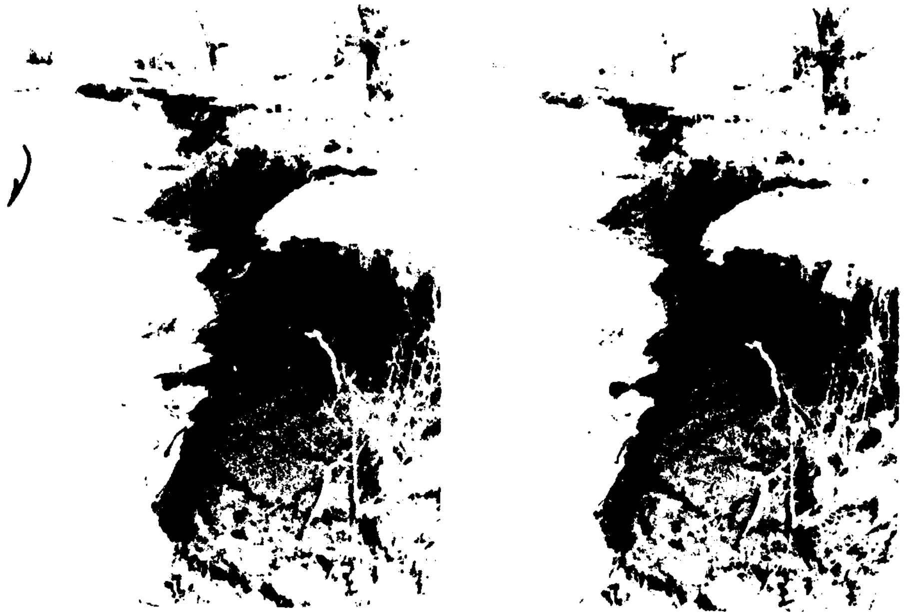
AERIAL VIEW
15 MAY 1979

FROM STATION 8+80
8 APRIL 1980

FROM STATION 8+80
3 DECEMBER 1980

SCHEME 2 PHOTOS
MOUNDSVILLE, W.VA. GRAVE CREEK
SITE
OHIO RIVER

PLATE 28



STEREOSCOPIC VIEW DURING
CONSTRUCTION TAKEN FROM
STATION 15+50
29 MARCH 1978

DURING CONSTRUCTION
FROM STATION 15+00
12 MAY 1978

FROM STATION 15+00
27 JUNE 1978

SCHEME 3 PHOTOS
MOUNDSVILLE, W.VA. GRAVE CREEK
SITE
OHIO RIVER

PLATE 29

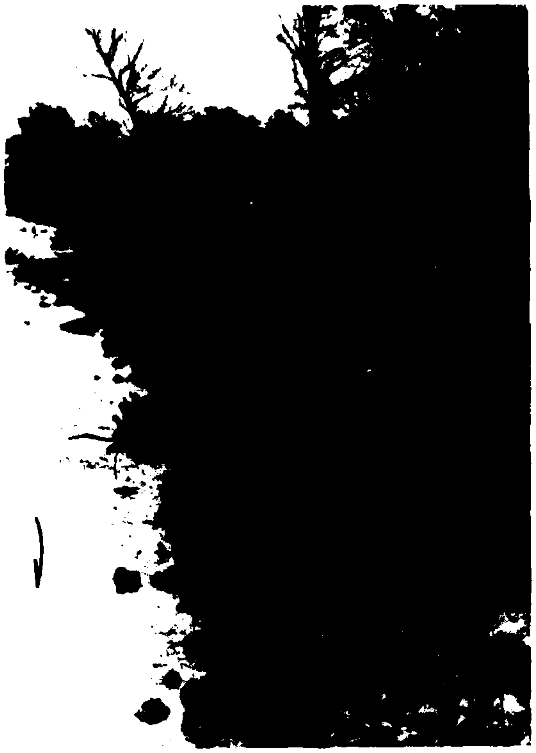
FROM STATION 15+00
21 DECEMBER 1978

FROM STATION 15+00
26 APRIL 1979

AERIAL VIEW
15 MAY 1979

SCHEME 3 PHOTOS
MOUNDSVILLE, W.VA. GRAVE CREEK
SITE
OHIO RIVER

PLATE 30



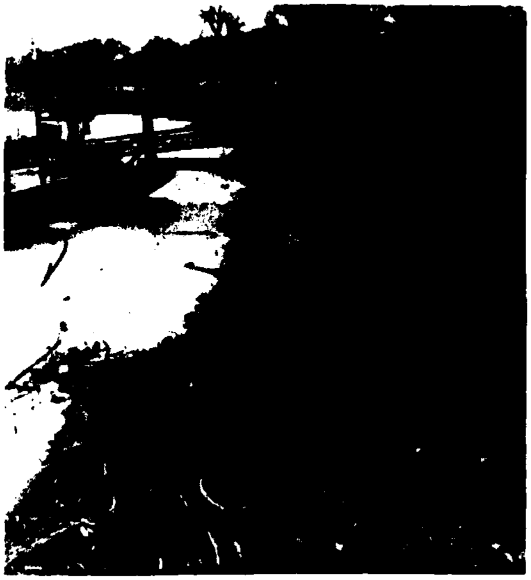
FROM STATION 15+00
25 OCTOBER 1979

FROM STATION 15+00
8 APRIL 1980

FROM STATION 15+00
3 DECEMBER 1980

SCHEME 3 PHOTOS
MOUNDSVILLE, W.VA. GRAVE CREEK
SITE
OHIO RIVER

PLATE 31



DURING CONSTRUCTION
FROM STATION 18+50
12 MAY 1978

FROM STATION 18+50
27 JUNE 1978

FROM STATION 18+50
24 OCTOBER 1978

FROM STATION 18+50
21 DECEMBER 1978

SCHEME 4 PHOTOS
MOUNDSVILLE, W.VA. GRAVE CREEK
SITE
OHIO RIVER

PLATE 32

FROM STATION 18+50
26 APRIL 1979

AERIAL VIEW
15 MAY 1979

SCHEME 4 PHOTOS
MOUNDSVILLE, W.VA. GRAVE CREEK
SITE
OHIO RIVER

PLATE 33

FROM STATION 18+50
25 OCTOBER 1979

FROM STATION 18+50
8 APRIL 1980

FROM STATION 18+50
3 DECEMBER 1980

SCHEME 4 PHOTOS
MOUNDSVILLE, W.VA. GRAVE CREEK
SITE
OHIO RIVER

PLATE 34

DURING CONSTRUCTION
FROM STATION 21+00
12 MAY 1978

FROM STATION 21+50
27 JUNE 1978

FROM STATION 21+50
24 OCTOBER 1978

FROM STATION 21+50
21 DECEMBER 1978

SCHEME 5 PHOTOS
MOUNDSVILLE, W.VA. GRAVE CREEK
SITE
OHIO RIVER

PLATE 35

FROM STATION 20+50
6 MARCH 1979

FROM STATION 21+50
26 APRIL 1979

SCHEME 5 PHOTOS
MOUNDSVILLE, W.VA. GRAVE CREEK
SITE
OHIO RIVER

PLATE 36

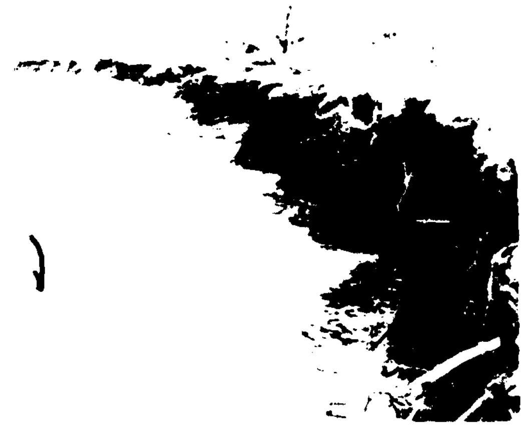
AERIAL VIEW
15 MAY 1979

FROM STATION 21+50
25 OCTOBER 1979

FROM STATION 21+50
8 APRIL 1980

SCHEME 5 PHOTOS
MOUNDSVILLE, W.VA. GRAVE CREEK
SITE
OHIO RIVER

PLATE 37



DURING CONSTRUCTION
FROM STATION 23+00
29 MARCH 1978

DURING CONSTRUCTION
FROM STATION 23+00
12 MAY 1978

FROM STATION 23+00
27 JUNE 1978

FROM STATION 23+00
24 OCTOBER 1978

SCHEME 6 PHOTOS
MOUNDSVILLE, W.VA. GRAVE CREEK
SITE
OHIO RIVER

PLATE 38

FROM STATION 23+00
21 DECEMBER 1978

FROM STATION 23+00
6 MARCH 1979

FROM STATION 23+00
26 APRIL 1979

FROM STATION 23+00
8 APRIL 1980

SCHEME 6 PHOTOS
MOUNDSVILLE, W.VA. GRAVE CREEK
SITE
OHIO RIVER

PLATE 39

OHIO RIVER
MOUNDSVILLE, WEST VIRGINIA

Section 32 Program Streambank Erosion Control
Evaluation and Demonstration Act of 1974

OHIO RIVER DOWNSTREAM OF MOUNDSVILLE, WEST VIRGINIA
DEMONSTRATION PROJECT PERFORMANCE REPORT

I. INTRODUCTION

A. Project Name and Location. Moundsville, West Virginia, Demonstration Project, Ohio River - mile 106.5, 4 miles downstream of Moundsville, W. Va. Plate 1 shows the project location.

B. Authority. Streambank Erosion Control Evaluation and Demonstration Act of 1974, Section 32, P.L. 93-251.

C. Purpose and Scope. This report describes a bank erosion problem, the types of protection used, and a performance evaluation of a demonstration project on the Ohio River designed and monitored by the Pittsburgh District.

D. Problem Resume. The left bank of the Ohio River was subject to active erosion which was undercutting mature trees and was encroaching on agricultural land which had been converted to use as a golf course. The property owner, a non-profit corporation, had attempted to protect the bank using brick and concrete rubble with limited success.

II. HISTORICAL DESCRIPTION

A. Stream Description, General.

1. Topography. The Ohio River at the demonstration site drains an area of 25,500 square miles covering primarily Pennsylvania west of the Allegheny Mountains and extending into portions of Ohio, West Virginia, New York, and Maryland. Major tributaries are the Allegheny, Monongahela, and Beaver Rivers. The topography of the basin is characterized by mature development of the drainage systems within the Allegheny plateau physiographic province. From its origin at Pittsburgh the river descends 90 feet along a course of 106.5 miles to the demonstration site. Relief at the site is approximately 700 feet from the river to the top of the surrounding valley walls. The river flows south at the demonstration site following a sinuous course with curves varying from 45 degrees to 180 degrees and radii of 1 to 2 miles. The natural stream gradient in this area is about 0.5 foot per mile. The valley floor averages about 0.6 mile in width. Stream banks average from 17 feet at Wheeling to several feet above normal pool at the Hannibal Lock and Dam. The Moundsville demonstration site is near the downstream end of Round Bottom which extends along the river for 4 miles on the inside of a sharp northwestern bend.

2. Geology. The Ohio River throughout its course along the West Virginia-Ohio border has become entrenched in sedimentary strata of Pennsylvanian and Lower Permian Age. These strata are made up of interbedded sandstones, siltstones, clays, shales, limestones, and coals. The bedrock valley of the Ohio River contains an alluvial fill of outwash from the Wisconsin Continental Glacier. In the portion of the Ohio Valley within the study area the alluvial fill is predominantly gravel, sand and gravel, and gravelly sand. Since the last glacial episode, the Ohio River has been cutting down through the alluvium with the formation of river terraces at various elevations in the Wisconsin fill and a well defined flood plain. In the study area, the Ohio River is still underlain by the Wisconsin alluvial fill to depths of 35 to 60 feet. A

layer of fine grained alluvium, averaging 10 to 30 feet in thickness, has been deposited on the flood plain by inundations of Ohio River floodwaters.

The Ohio River channel has been shifting back and forth across the alluvium which fills the bedrock valley. The channel is thus frequently located asymmetrically on one side of the old bedrock valley. In these areas, one bank consists of the highly erodible flood plain deposits and the other consists of rock out-crops or colluvial soil which has accumulated through weathering and creep of the hillsides above. The colluvial soils are generally stiff to hard silty clays with angular rock fragments and little or no layering. These soils tend to resist erosion and seem to erode at a much slower rate than flood plain deposits.

Round Bottom, on which the Moundsville demonstration site is located, is a flood plain with bedrock found at elevations of 558 to 572 feet. Test holes drilled for a chemical plant near the demonstration site show fine grained allu.ium to depths of 30 to 40 feet underlain by sand and gravel to the top of bedrock.

3. Locality, Development, and Occupation. The Ohio River valley in the vicinity of the demonstration site has developed a diverse industrial character. Over the past several decades most of the broad agricultural bottoms have been acquired for industrial development. Within the Hannibal navigation pool the river valley contains several large cities and towns, including Wheeling, Moundsville, and New Martinsville in West Virginia, and Martins Ferry, Bellaire, and Shadyside in Ohio. Local industries include coal mining, steel, chemical and aluminum production, electric power generation, and a variety of light manufacturing. The river is paralleled by railroads and highways on both banks.

The Ohio River has been an important transportation artery since prehistory and has undergone navigation improvements since 1824 when Congress provided for removal of obstructions such as bars and snags. For many years river navigation was facilitated solely by open channel

improvements. In addition to removal of channel obstructions, stone training dikes were constructed at various bars in order to constrict the channel and increase the scour of the river. The first movable dam on the Ohio River was located at Davis Island, 4.7 miles below Pittsburgh, and opened to commerce October 7, 1885. A system of locks and movable dams was eventually constructed along the entire Ohio River. In August 1917, Lock and Dam 14 was put into operation 7 miles downstream of the demonstration site. These early dams incorporated a navigable pass to provide a channel for open river navigation during periods of high flow. A series of wickets, heavy timber shutters, were raised to impound water as needed to maintain a navigation pool. When not required, the wickets would lie flat at such a depth as to offer no obstruction to free navigation through the pass. Replacement of these original navigation dams with fixed, gated structures having higher lifts has been ongoing. In 1975, Hannibal Locks and Dam went into full operation and Locks and Dams 12, 13 and 14 were removed.

4. Hydrologic Characteristics. The Ohio River valley in the vicinity of the demonstration site is subject to a continental climate with high and low temperature extremes of 95 degrees to 105 degrees F., and -15 degrees to -25 degrees F. The mean annual temperature averages 50 degrees F. The growing season extends from late April to mid-October. Normal annual precipitation is approximately 40 inches per year. The flood of record occurred in March 1936 with a maximum discharge of 450,000 c.f.s. in the vicinity of the demonstration site. This flow exceeded the 500-year flood and, at the demonstration site, overtopped the bank by 12 feet. A stage frequency curve is shown on Plate 2. A one-year flood hydrograph is shown on Plate 3.

5. Existing Channel Conditions. The sinuosity of the channel was described in paragraph II.A.1. The channel location has been relatively stable within historical time. A discharge rating curve for the river at the site location is shown on Plate 2.

6. Environmental Considerations. A minor amount of farming is practiced in the few remaining undeveloped portions of the river valley. This is being accomplished under lease from the industries in the area who own these properties and are reserving them for future expansion of facilities. The steep hillsides adjacent to the valley floor are primarily undeveloped and consist of second growth woodlands. Within the flood plain, vegetation associated with farming and frequent site disturbance prevails. Along the river bottom land, silver maple and sycamore occur most frequently, while elm, cottonwood, buckeye and willow are present with somewhat reduced representation. On the hillsides and in areas of greater stability above ordinary high water, oaks, beech, red maple, ash, black cherry and walnut exist. Timber stands adjacent to the river are generally of low quality because of physical damage caused by ice and floating debris during high water. Nails, spikes, eye bolts, cables and physical damage from river traffic are also evident in many specimens.

Both fish and wildlife resources of significance are found in the project area. Fishes include such species as channel catfish, carp, spotted bass, largemouth bass, smallmouth bass, white bass, pumpkinseed, bluegill, white crappie, shiners, perch, skipjacks, gizzard shad and golden redhorse. Excellent warm-water fisheries have developed at or near the mouths of several of the tributary streams. Wildlife resources also include a variety of species. Mourning doves, bobwhite quail and cottontail rabbits are present in the agricultural areas, while ruffed grouse and squirrels inhabit the uplands. White-tailed deer are present in the adjacent uplands and also range into the valley. The Ohio River also provides resting and feeding opportunities for several species of migratory waterfowl. Muskrat, mink, raccoon and fox are some of the fur animals in the area.

This reach of the river, as with the entire Ohio in general, is exposed to various types of pollution which tend to affect aquatic life and generally detract from the aesthetic value of the river. Excessive amounts of organic matter, chemicals, sediment and colloidal particles

contribute to the relatively poor water quality, with seasonal variations experienced as a result of changes in flow and temperature.

The use of steel furnace slag in demonstration schemes which specify structural protection may also result in a level of water quality degradation commensurate with the bulk chemical content of the slag and the availability of its chemical constituents to the Ohio River as a result of leaching and weathering. Fines may also enter the Ohio River as a result of slag erosion.

Plate 4 provides a comparison of results of leachability tests performed on slag used at the demonstration site with Ohio River water quality near the Moundsville site and relevant water quality criteria and standards.

7. Environmental Effects. During the proposed work, disturbance of the river bed and bank would result in temporary, construction-related increases in turbidity and suspended matter in the Ohio River downstream of the project site, which would be confined to an approximate 45-day construction period. Grading and recontouring of the bank slope would result in the loss of established herbaceous and woody vegetation and exposure of disturbed soil to river currents and weathering. Filter cloth matting would aid in the retention of exposed soil prior to revegetation. The use of air-cooled basic oxygen furnace slag in schemes which specify structural protection may result in a level of water quality degradation commensurate with the bulk chemical content of the slag and the availability of its chemical constituents to the Ohio River as a result of leaching and weathering. However, the quantities of slag involved, weathering and aging of the slag surface and gradual revegetation would tend to minimize the level of chemical constituents leached from the slag. The required excavations would diminish habitat diversity within the riverine littoral region and along the protected shoreline, but would not result in the loss of significantly productive shallow water habitat or aquatic or terrestrial cover necessary to sustain a locally diverse fish or wildlife population.

Both short and long-term benefits would accrue as a result of the proposed action: (1) One or more optimum designs of bank protection would be determined as a result of periodic monitoring and studies of the relative durability of the various demonstration project schemes. (2) The proposed demonstration project schemes may collectively relieve the acute bank erosion problem at each of the proposed test sites.

B. Demonstration Project.

1. Hydrologic Characteristics. Hydrographs for the demonstration site are shown on Plates 5 and 6. Channel cross-sections are shown on Plate 7. The river channel in the vicinity of the demonstration site has been subject to commercial sand and gravel dredging at various times in the past. Ice formation in the project area becomes significant only during unusually severe winters. Ice movement is not a factor in bank erosion at the site.

2. Hydraulic Characteristics. Velocity distributions through the test reach for a range of flow conditions are shown on Plate 8. Twenty discharge measurements (649 velocity observations) were made for flows between 12,000 cfs and 104,000 cfs. These observations were analyzed by linear regression and found to agree with a District Computational Method[1/] within 1/4 foot per second 81% of the time. From this it can be assumed that prototype velocities can be reliably approximated with a minimum of field verification. This rationale will be used at other sites, where possible, due to the difficulty, danger, and expense of obtaining boat measurement. Average river velocities at the site for given discharges are as follows:

1/ Seventeenth Congress of the International Association for Hydraulic Research, paper C-18, "Determination of Approach Velocities for Preliminary Siting of Navigation Structures," 1977 Baden-Baden.

Discharge (cfs)	Frequency of Occurrence (years)	Average Velocity (fps)
20,000		0.8
100,000		3.6
220,000		6.0
283,000	10	6.6
384,000 (1972 flood)		6.7
398,000	100	7.7

Piezometers were installed at the demonstration site and monitored twice per week. Plate 9 shows the piezometer locations and Plates 10 and 11 are plots of the piezometric levels and the river stage. Wave action was observed visually under various wind and traffic conditions. The maximum observed wave height was approximately one foot and was induced by traffic during low flow conditions. The minimum pool elevation is maintained at elevation 623 by the operation of Hannibal Locks and Dam, 20 miles downstream. Flows are controlled by eight gated bays, each 110 feet long, and a 110-foot long fixed weir section. The dam gates are raised to pass high flows, so that the influence of the dam on the river decreases with increasing flow. At the demonstration site the influence of the dam during floods is insignificant. Prior to the completion of the Hannibal Project in 1975 the river at the demonstration site was maintained at minimum pool elevation 610.5 by Lock and Dam 14. The operation of the wicket type dams is described in paragraph II.A.3.

3. Riverbank Description. The riverbank at the demonstration site is composed of fine grained alluvian deposited by past flood events in a thinly interbedded structure of fine sands, silts, and clays. Plate 12 shows the logs of the borings made for the installation of piezometers. The landward area is planted with grass and is mowed to within several feet of the top of bank. A few mature trees grow near the top of bank along the demonstration reach.

Erosion at the site is episodic with the majority of bank loss occurring during or immediately following periods of high water. The primary erosion mechanisms at this site are sloughing and piping

followed by removal of the disturbed soil by river flows. Sloughing is the stability failure of a block of bank soil that results from saturation during high water and the related pore pressure and weight increase following the subsequent drawdown. Piping is the development of cavities in the bank face resulting from groundwater seepage concentrating in the more permeable sandy layers in the bank. The passage of water along these layers tends to remove individual particles of granular material at the face of the bank, in turn removing support for overlying materials.

Erosion at the site was brought to the attention of the District in April 1971, well before the establishment of the Hannibal pool. The site was converted from agriculture to a golf course in the sixties. Although erosion conditions while under agricultural use are unknown, the change in land use, with its attendant changes in site grading, vegetation, and drainage may have contributed to the instability of the bank. Plate 13 shows the condition of the bank prior to the demonstration project.

III. DESIGN AND CONSTRUCTION

A. General. The Moundsville site presented the opportunity to evaluate different schemes of bank protection along a relatively uniform reach of river located with good landward access and where erosion had been a chronic problem. Six schemes were designed to compare varying combinations of structural and vegetal methods of bank protection.

B. Basis for Design. The structural features were a series of variations on the conventional stone bank protection design used by the District at that time. Steel furnace slag was used in lieu of stone because it is an economical, locally available material. The slag is a durable high density by-product of the basic oxygen or electric furnace steel making processes and should not be confused with lighter density

blast furnace slag. The slag is graded into various sizes by the suppliers for sale as highway materials, railroad ballast, or fill material. The size range used for bank protection includes a varying percentage of refractory brick from ladle or furnace linings. The refractory material is a durable and angular component of the bank protection. Where a filter was placed between the slag protection and the underlying soil, a woven polypropylene filter fabric was used. The vegetal features included a variety of shrubs, legumes, and grasses planted or seeded in subsections within each scheme of protection. The plants were chosen on the basis of recommendations from other agencies, findings in the literature, and District experience. In addition to the protection constructed by the District, the project incorporated a 560-foot long reach of building rubble previously placed as bank protection by the property owner.

C. Construction Details

1. Scheme 1. This 330-foot reach of protection was constructed by excavating the bank to a one vertical on two horizontal minimum slope and placing an 8-inch minimum thickness of graded steel furnace slag from the pool elevation, el. 623, to elevation 626 atop filter fabric. From elevation 626 to the top of slope various shrubs were planted on a 2-foot grid spacing through a biodegradable erosion control mat. The slag was well graded between 2 and 12 inches. Details of Scheme 1 are shown on Plate 14.

2. Scheme 2. Scheme 2 is 350 feet long and was constructed in the same manner as Scheme 1 except that the slag protection was placed to a greater height on the slope, elevation 628, and the upper slope was seeded with legumes and grasses. Two different toe configurations were placed. Details of Scheme 2 are shown on Plate 15.

3. Scheme 3. This scheme, also 350 feet long, was varied from Scheme 2 by increasing the thickness of the slag protection from 8 inches to 12 inches. The slope above elevation 628 was seeded and two

different toe configurations were placed. See Plate 16 for details of Scheme 3.

4. Scheme 4. Scheme 4 is 300 feet long and was constructed as a purely vegetal form of bank protection. The bank was excavated to a one vertical on two horizontal slope and planted with various shrubs on a 2-foot grid spacing. The shrubs were planted through filter fabric from the pool elevation, el. 623, to elevation 628, and through a biodegradable erosiion control mat from elevation 628 to the top of slope. See Plate 17 for details of Scheme 4.

5. Scheme 5. Scheme 5 was constructed along a 400-foot reach with combined structural and vegetal features. From elevation 622, one foot below pool, to elevation 626 the bank is protected with an 18-inch minimum thickness of slag well graded between 2 and 18 inches in size. The slag was placed without a filter. From elevation 626 to the top of the slope a variety of shrubs were planted on a 2-foot grid spacing through a biodegradable erosion control mat. The upper bank was graded to a one vertical on one and one-half horizontal minimum slope prior to placement of the protection. Plate 18 shows details of Scheme 5.

6. Scheme 6. Scheme 6, also 400 feet long, was constructed in the same manner as Scheme 5 except that the slag protection was placed to elevation 628 and the upper bank slope was graded to a one on one slope and seeded with legumes and grasses. See Plate 19 for details of Scheme 6.

D. Costs. The contractor received notice to proceed on 20 October 1976 and the final inspection was held on 17 May 1977. The final contract cost was $113,335 with no modifications. The unit prices for the contract included $10 per cubic yard for 3,800 cubic yards of unclassified excavation, $25 per cubic yard for 1,500 cubic yards of slag protection, $4 per square yard for 1,800 square yards of filter cloth, $5 each for 6,677 plants, and $4 per square yard for 1,500 square yards of seeding and mulching. The final construction cost per

linear foot and per square foot of protection for each scheme was as follows:

Scheme	Cost per Linear Foot	Cost per Square Foot
1 (structural)	$28	$4.04
1 (vegetal)	$25	$2.10
2	$37	$3.38
3	$50	$4.52
4	$76	$3.03
5 (structural)	$28	$3.56
5 (vegetal)	$31	$1.11
6	$39	$3.00

The supervision and inspection cost was $15,050 and the engineering and design cost was $32,300.

IV. PERFORMANCE OF PROTECTION

A. Monitoring Program. The Pittsburgh District Section 32 monitoring program is summarized on Plate 20. Instrumentation at the site comprises three piezometers, installed as shown on Plate 21, a recording wind measuring device, and a staff gage. The recording wind measuring device, a model S.A. 451-2, Mark III, was installed in December 1977 and was removed during 1980 because of damage. Plate 22 shows a wind rose depicting the directional percent of time at the site. The three highest average speeds were:

4.8 miles per hour from NNW direction

4.5 miles per hour from SSE direction

3.9 miles per hour from N direction

The lowest average speed was 1.1 mph from due east while the due west velocity, in the direction of the bank protection, was 2.6 mph. Air temperature and precipitation are measured at the Hannibal and Pike Island navigation projects. The piezometers are read twice weekly and the staff gage is read twice daily by a paid observer. Monitoring inspections by project designers have been made on the average once every two months. These inspections include visual observations and photographs taken from fixed reference points. Overbank cross-sections were surveyed before construction, in July 1976, in April 1977 near the end of construction, and in June 1979. The site will be resectioned in April 1982. Soil samples were taken at the site in March 1977 and were tested for gradation, water content, Atterberg limits, and agronomic properties. Quantitative leachate analyses of slag were made on samples taken at potential supply sources in January 1975 and July 1976, and on samples taken from in-place bank protection in August 1978 and February 1980. Further testing of in-place slag is scheduled for 1981, 1982, and 1983. Controlled vertical low level aerial photography was taken in the spring of 1977, fall of 1978, and spring and fall of 1980. Low angle oblique aerial photography was taken in the fall of 1978 and the spring of 1979. Plates 23 and 24 show vertical aerial photographs of the site taken in September 1978 and March 1980.

B. Evaluation of Protection Performance.

1. General. After several episodes of high water, an erosion scarp began to develop at approximate elevation 631 in the vegetated upper bank slope along the entire reach of the project. Apparently, the river rises to this elevation sufficiently often, with an approximate one-year recurrence interval, to produce a marked change in the bank slope protected with shrubs and grasses having only a single growing season to establish. Over the monitoring period, some areas of vegetal protection have developed sufficiently to retard the progression of the scarp while in others the scarp has progressed to over 5 feet high and is approaching the top of bank.

An improper construction technique caused problems with the performance of the lower bank protection features. The project design called for achieving the minimum slopes through excavation of the original eroded bank face. On the basis of project performance and observations during construction, it appears that much of the project was constructed by excavation of the upper bank slope and filling of the lower bank slope with loose soil from the cut above. Early in the monitoring period all of the lower slope structural features showed varying degrees of distress due to the settlement of slag protection placed atop loose soil fill. In Scheme 4, with no structural protection, rapid erosion of the lower slope exposed piles of shale and concrete rubble, the results of earlier protection efforts. These were to have been removed prior to grading the slope, but were instead covered by soil cut from the slope above. The failure and reconstruction of Scheme 4 is described in greater detail below.

2. Scheme 1. The 8-inch thick lower bank slag protection has been generally effective to the limit of its placement, elevation 626. Areas of settlement at the toe have caused localized oversteepening, shifting of the slag, and consequent exposure of the underlying filter cloth. In some of these areas the filter cloth has bulged and split, resulting in gaps in the protection. There are four such areas with the largest being 10 feet in lateral extent. The upper bank exhibits a moderate advance of the high water erosion scarp described above. The Red Osier Dogwood has shown the best performance of the shrubs in Scheme 1 with 90% of the planted section growing and the plants in excellent condition. The least successful is the speckled alder with 5% of the planted section growing and the plants in poor condition. The performance of all the vegetal features of the project is summarized on Plate 25. Sequential photos of Scheme 1 are shown on Plates 26, 27 and 28.

3. Rubble Zone. Much of the building rubble placed by the property owner was common brick which deteriorated rapidly under exposure to the elements. Top of bank recession has continued slowly through the monitoring period along most of this zone. Plates 29 and 30 show photos of the rubble zone.

4. Scheme 2. The 8-inch thick lower bank protection placed to elelvation 628 has been effective and has not shown distress due to the settlement as in Scheme 1. Although marked by the high water erosion scarp, the upper bank is relatively stable. The reed canarygrass and crown vetch have shown the best growth; however, the crown vetch has taken over or is invading almost all sections of the upper bank. Photos of Scheme 2 are shown on Plates 31 and 32.

5. Scheme 3. The 12-inch thick lower bank protection has been effective, although filter cloth has been exposed in two areas, apparently due to the toe settlement problem. The largest of these areas grew to 15 feet in lateral extent and was rehabilitated with additional slag at the time Scheme 4 was reconstructed. The upper bank slope is relatively stable. The seed mixtures containing reed canarygrass and crown vetch have performed the best. As in Scheme 2, the crown vetch has taken over or is invading most areas of the upper bank. Photos of Scheme 3 are shown on Plates 33, 34 and 35.

6. Scheme 4. The lower slope of this scheme, protected only with plantings failed within a year after construction. As explained in paragraph IV.B.1, the construction practice of excavating the upper slope and filling the lower slope resulted in a slope constructed partially of loose disturbed material. By the fall of 1977, bulging at the toe and stretching of the filter cloth on the lower slope was obvious. The bulging was caused by soil eroded from the slope accumulating at the buried toe of the filter cloth and remaining trapped there. Through the remainder of 1977 and early 1978 the filter cloth continued to bulge riverward at the toe and pull away from the bank at the top. Photographs on Plates 36 and 37 show the deterioration of the slope. By May 1978, sufficient filter cloth was pulled free from the slope to reveal severe erosion of the lower slope along most of the reach of Scheme 4. The erosion was characterized by an 8 to 20 foot long slope of IV:5H or flatter, extending from the water's edge to the toe of a 3 to 5 foot high scarp varying in slope between 1:1 and near vertical. The reconstruction performed in the summer of 1978 will be detailed in

paragraph IV.C. The reconstructed lower slope has been effective. On the planted upper slope the Purple Osier Willow and the Red Osier Dogwood have performed the best with 80% of the planted section growing for each. The lowbush blueberry is the least successful with only 20% of the planted section growing.

7. Scheme 5. The lower slope slag protection of this scheme has performed effectively. Some signs of toe settlement appeared within a year of construction but have since stabilized. The lack of a filter has not been deterimental to the performance of this relatively thick slag protection. The upper bank erosion has reached its greatest development in this scheme with a maximum scarp height of 5 to 6 feet. The Red Osier Dogwood shows the best growth while the speckled alder shows the worst with 90% and 10% of the planted sections growing respectively. Photos of Scheme 5 are shown on Plates 38, 39 and 40.

8. Scheme 6. The lower bank slag protection has been effective. As in Scheme 5, the absence of a filter has not been detrimental. The seeded upper bank with a steep one on one slope has been susceptible to erosion during high water. Upper bank erosion is less severe than in Scheme 5. Overall performance of the legumes and grasses has been inferior to the other schemes. Crown vetch has been the most successful specie and is invading other sections of the bank. Photos of Scheme 6 are shown on Plates 41, 42 and 43. In April 1979 a downstream bound tow ran aground within the limits of Scheme 6. The left front barge of the tow mounted the bank diagonally causing displacement of slag protection and the upper bank soil along a reach of 140 feet. The result was a ramp-like feature traversing the bank. Upper bank vegetation healed itself within one growing season. The slag protection was significantly damaged over a reach of 30 to 35 feet.

C. Rehabilitation. The rehabilitation of Scheme 4 was done between 17 July and 7 August 1978 as a supplement to the initial construction contract at a cost of $29,518. The repaired configuration consists of a sand and gravel fill to the original IV:2H slope protected by an 18-inch thick blanket of graded steel furnace slag with a 12-inch maximum

size. The protection has a toe buried one foot below minimum pool and extends to elevation 633, ten feet above pool. Plates 44 and 45 show a cross-section and photographs of the rehabilitation.

At the conclusion of the monitoring period some additional rehabilitation will be performed in the areas of filter cloth exposure and barge damage.

D. Summary of Findings.

1. Structural Features. Steel furnace slag has been shown to be an effective substitute for natural stone as graded bank protection. A 12-inch thick layer with a filter beneath is the minimum coverage on a 1V:2H slope that will perform reliably under the grading and placement tolerances expected in normal construction practice. An 18-inch thick placement of graded slag without an underlying filter was shown to be effective on steeper slopes. The height of structural protection on a bank slope should be at least equal to the river stage with a one-year recurrence interval as demonstrated by the upper bank erosion at this site. The grading technique and the resulting toe settlement problem at this site show that it can be more effective to have a contractor place a free draining fill to achieve minimum slopes than to excavate the in-situ soil. In addition, a sand and gravel fill provides an effective filter to permit drainage without loss of soil fines.

2. Vegetal Features. The upper bank erosion experienced at this site shows that plant shoots and seeding do not develop sufficiently in one growing season to protect a riverbank exposed to high water. Red Osier Dogwood (Cornus sericea) and Crownvetch (Coronilla varia "Penngift") were the most successful plants as shown by their development through the monitoring period. It should be noted, however, that heavy weed growth in some sections may have hindered other plants from succeeding. Thick stands of Bull Thistle (Cirisum vulgane) and Pokeweed (Phytolacca americana) completely crowded out some test plants.

Although other plants registered a relatively high score in evaluation, only Red Osier Dogwood and crown vetch showed the ability to crowd out weeds and "fill-in" between the original plants.

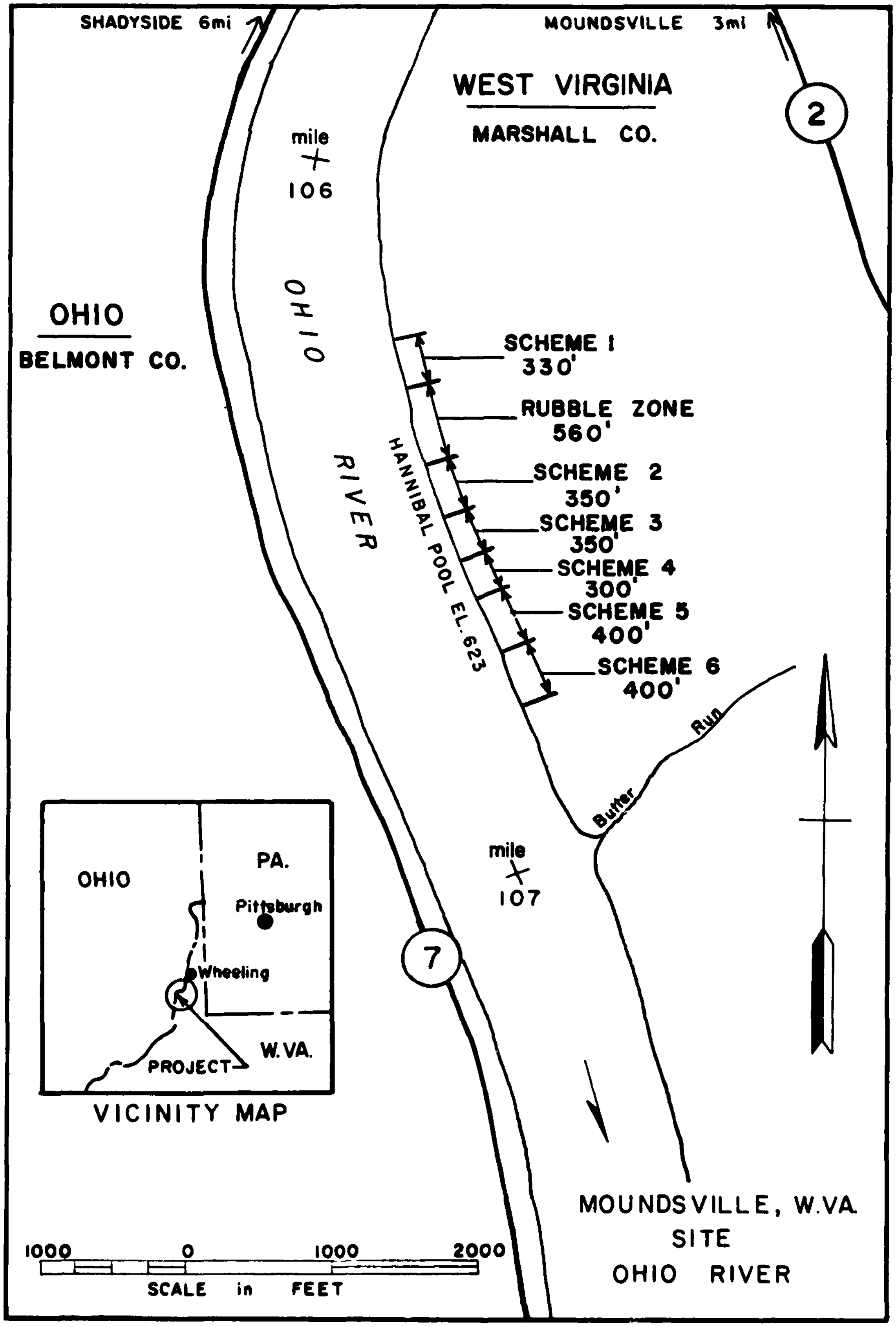
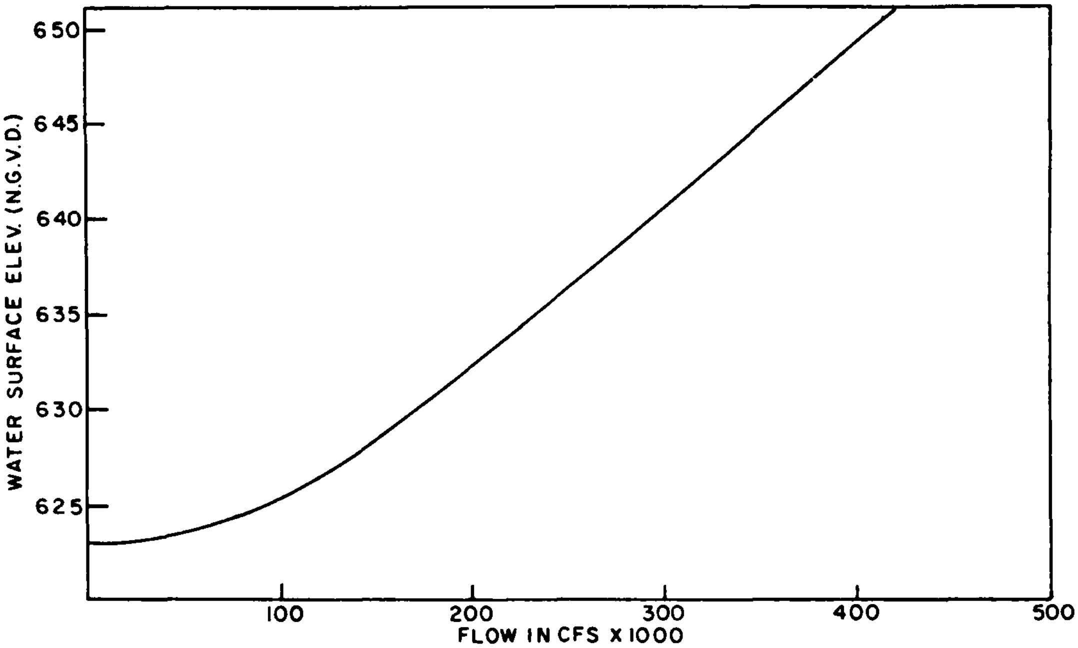
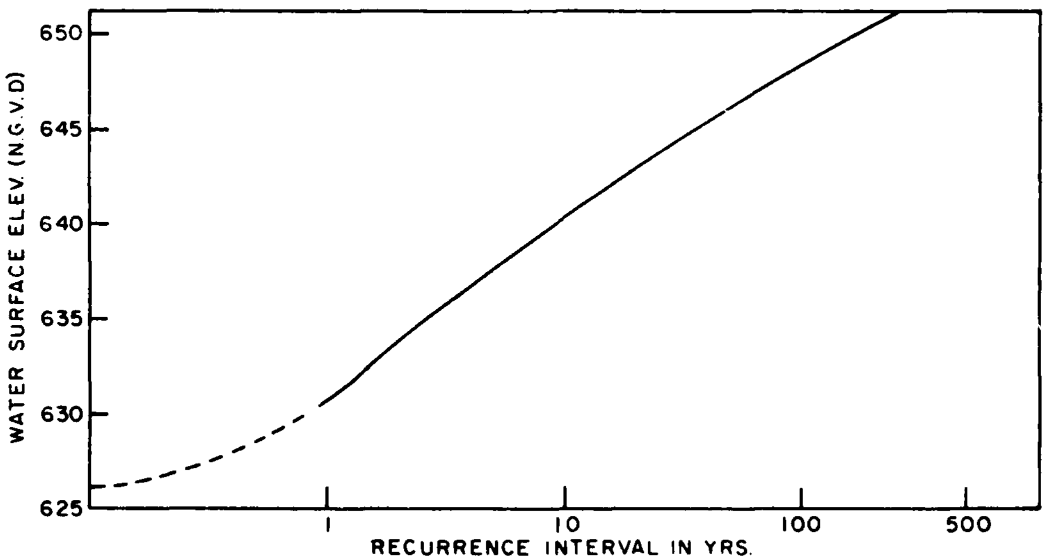

SHADYSIDE 6mi
MOUNDSVILLE 3mi
WEST VIRGINIA
MARSHALL CO.
2
mile
106
OHIO
BELMONT CO.
OHIO
RIVER
HANNIBAL POOL EL. 623
SCHEME 1
330'
RUBBLE ZONE
560'
SCHEME 2
350'
SCHEME 3
350'
SCHEME 4
300'
SCHEME 5
400'
SCHEME 6
400'
Butler Run
mile
107
7
OHIO
PA.
Pittsburgh
Wheeling
PROJECT
W.VA.
VICINITY MAP
1000 0 1000 2000
SCALE in FEET
MOUNDSVILLE, W.VA.
SITE
OHIO RIVER

PLATE 1



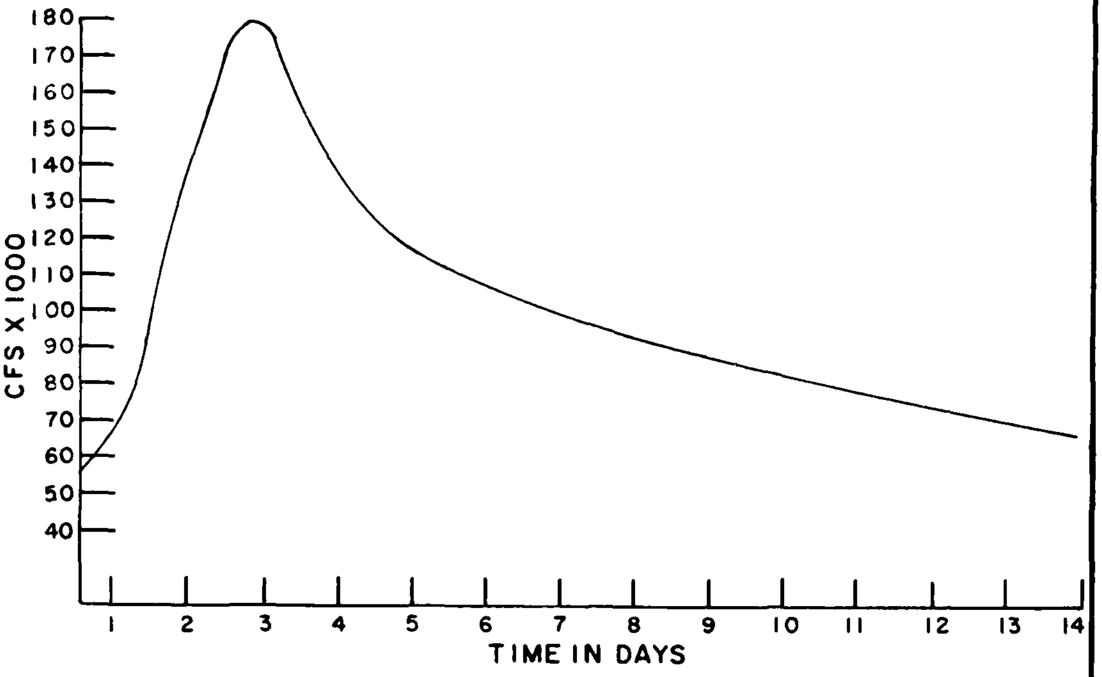
DISCHARGE RATING CURVE MI. 106.6



STAGE FREQUENCY CURVE MI. 106.6

DISCHARGE RATING CURVE
AND
STAGE FREQUENCY CURVE
MOUNDSVILLE, W. VA.
SITE
OHIO RIVER

PLATE 2



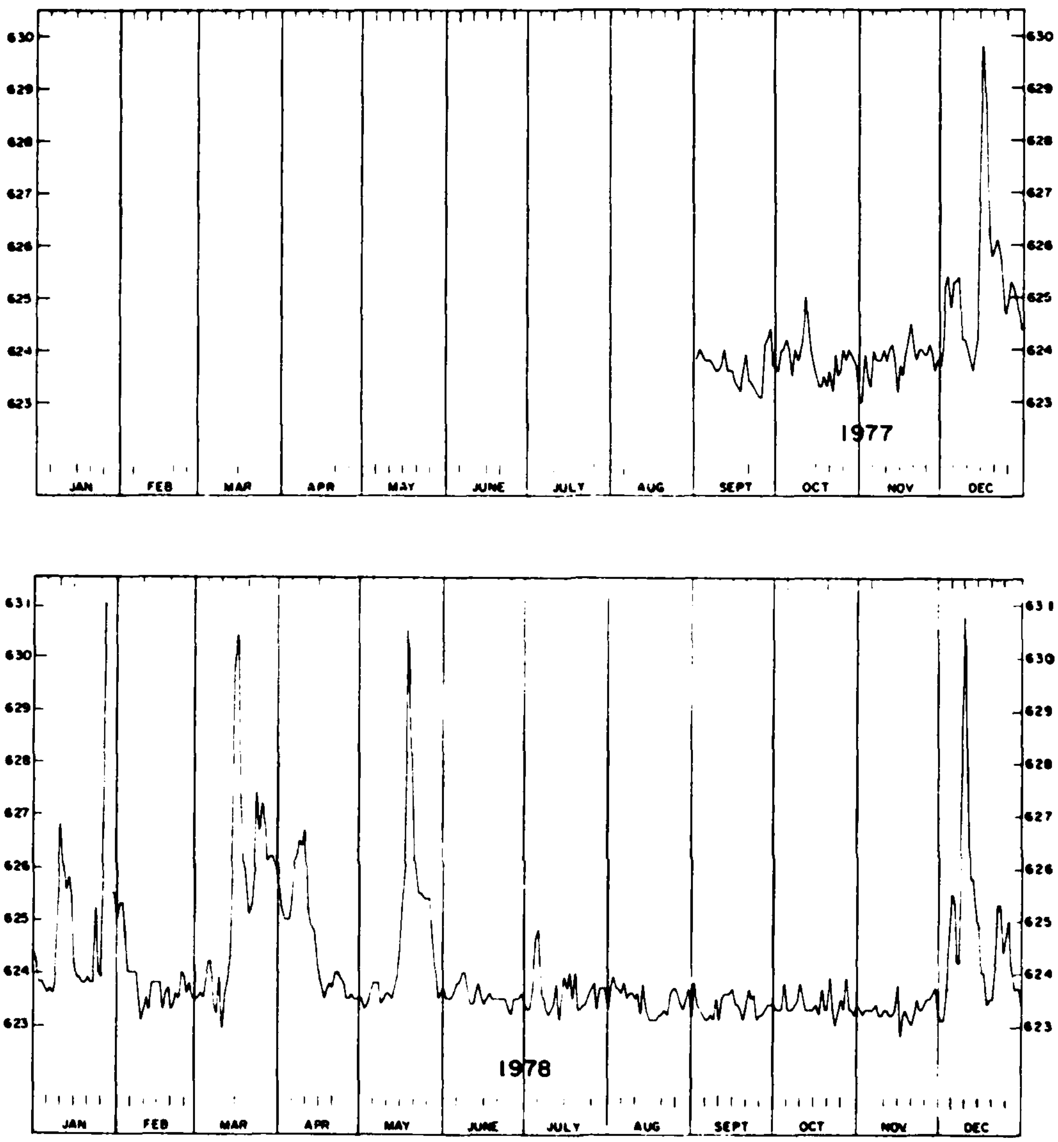
ONE YEAR FLOOD HYDROGRAPH
MOUNDSVILLE, W. VA.
SITE
OHIO RIVER

PLATE 3

PARAMETER mg/l	SLAG IN RIVER WATER	SLAG IN D.I. WATER	RIVER WATER	W. VA. CRITERIA 1980	EPA CRITERIA 1972
Alkalinity M.O.	86	73	44		
Arsenic (As)	< 0.005	< 0.005	< 0.005	0.05	0.01
Barium (Ba)	< 0.1	< 0.1	< 0.1	1.0	1.0
Cadmium (Cd)	< 0.01	< 0.01	< 0.01	0.01	0.01
Chloride (Cl)	42	1	32	250	250
Chromium (Cr^{+6})	0.003	0.003	0.002	0.05	0.05
Chromium Total	< 0.02	< 0.03	< 0.03		
Color (APHA)	5-10	0-5	20-30		75
Copper (Cu)	< 0.02	< 0.02	< 0.02	0.005	1.0
Cyanide Total (Cn)	0.012	0.003	0.020	0.025	0.2
Fluoride (F)	0.81	0.56	0.23	1.0	
Hardness ($CaCO_3$)	192	65	124		
Iron Total (Fe)	0.11	< 0.02	1.1	1.0	0.3
Lead (Pb)	< 0.05	< 0.05	< 0.05	0.05	0.05
Magnesium (Mg)	12	1.07	9.0		
Manganese (Mn)	0.12	0.03	0.34	0.05	0.05
Mercury (Hg) ug/l	< 0.2	< 0.2	0.6	0.2	2.0
Nitrate (N)	1.7	< 0.2	1.1	10.0	10.0
PH	7.0	7.7	7.7	6.0-9.0	5.0-9.0
Phenol	0.002	0.002	0.003	0.005	0.001
Selenium (Se)	< 0.005	< 0.005	< 0.005	0.005	0.01
Silver (Ag)	< 0.02	< 0.02	< 0.02	0.05	
Solids Dissolved	373	91	234		
Solids Suspended	6	< 1	16		
Solids Total	409	105	254		
Sulfate (SO_4)	125	3.5	98		250
Sulfide (S)	< 0.02	< 0.02	< 0.02		
Zinc (Zn)	< 0.02	< 0.02	< 0.02	0.05	5.0

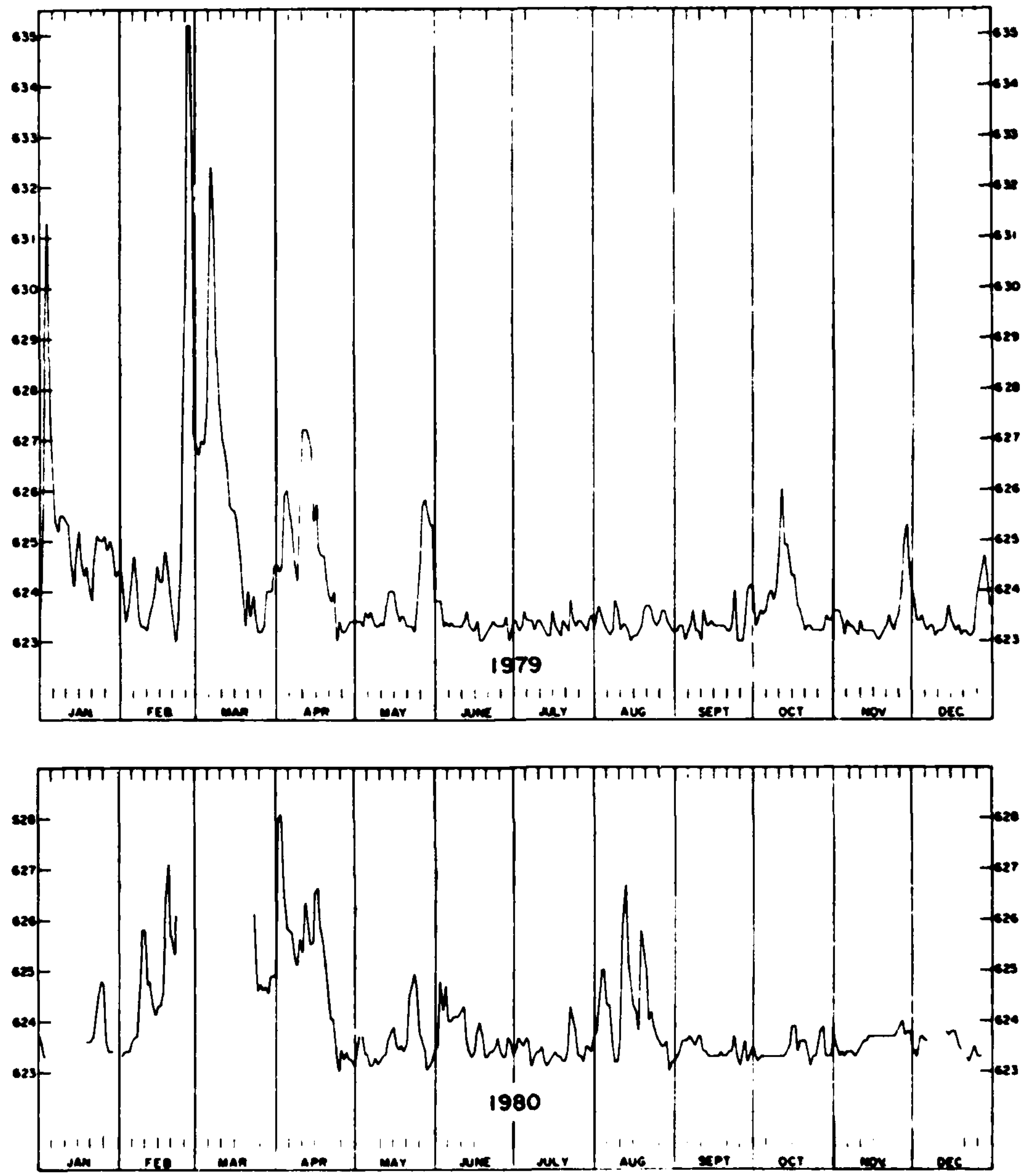
SLAG LEACHATE
COMPARISON
MOUNDSVILLE, W. VA.
SITE
OHIO RIVER

PLATE 4



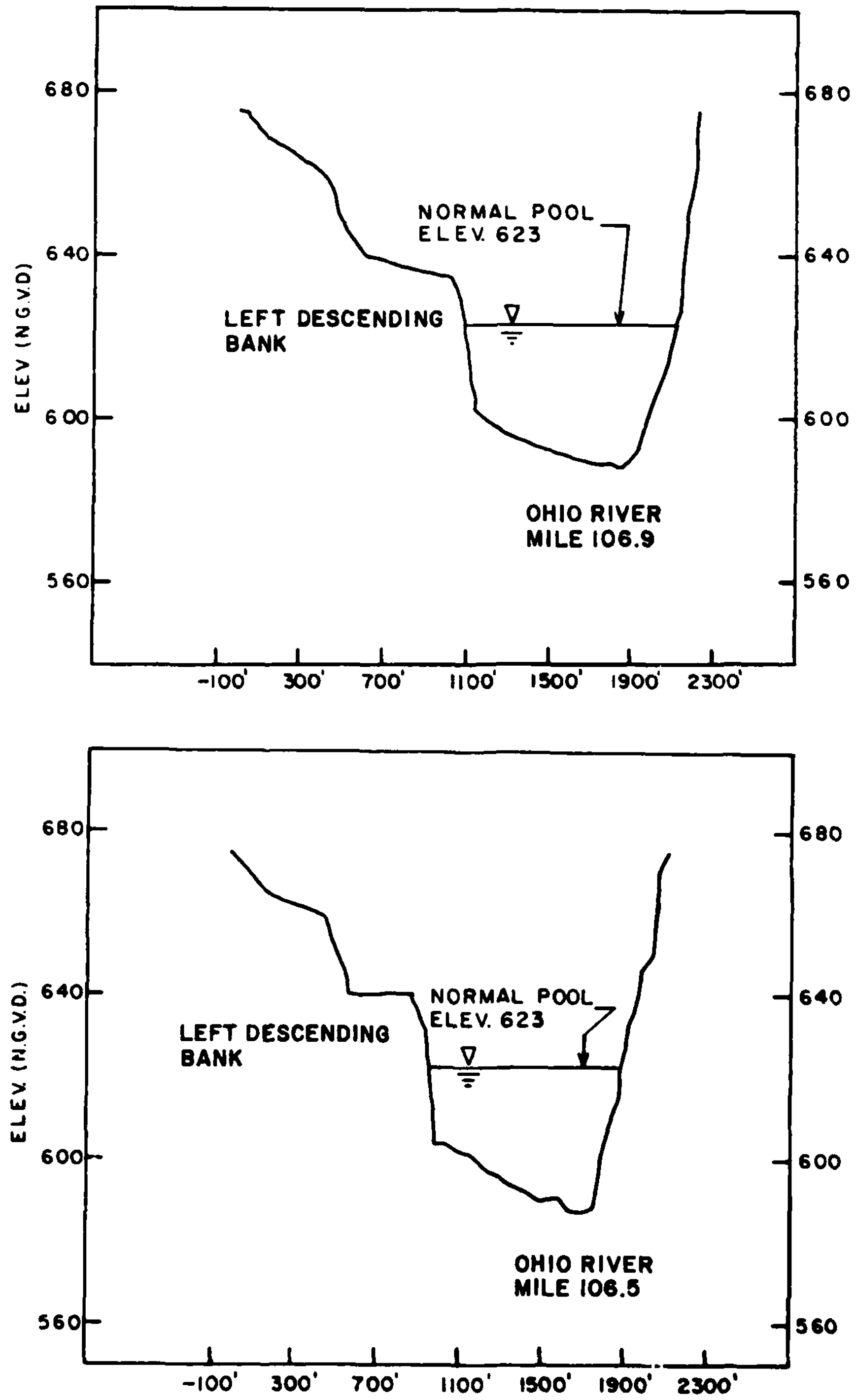
HYDROGRAPHS
MOUNDSVILLE, W. VA.
SITE
OHIO RIVER

PLATE 5



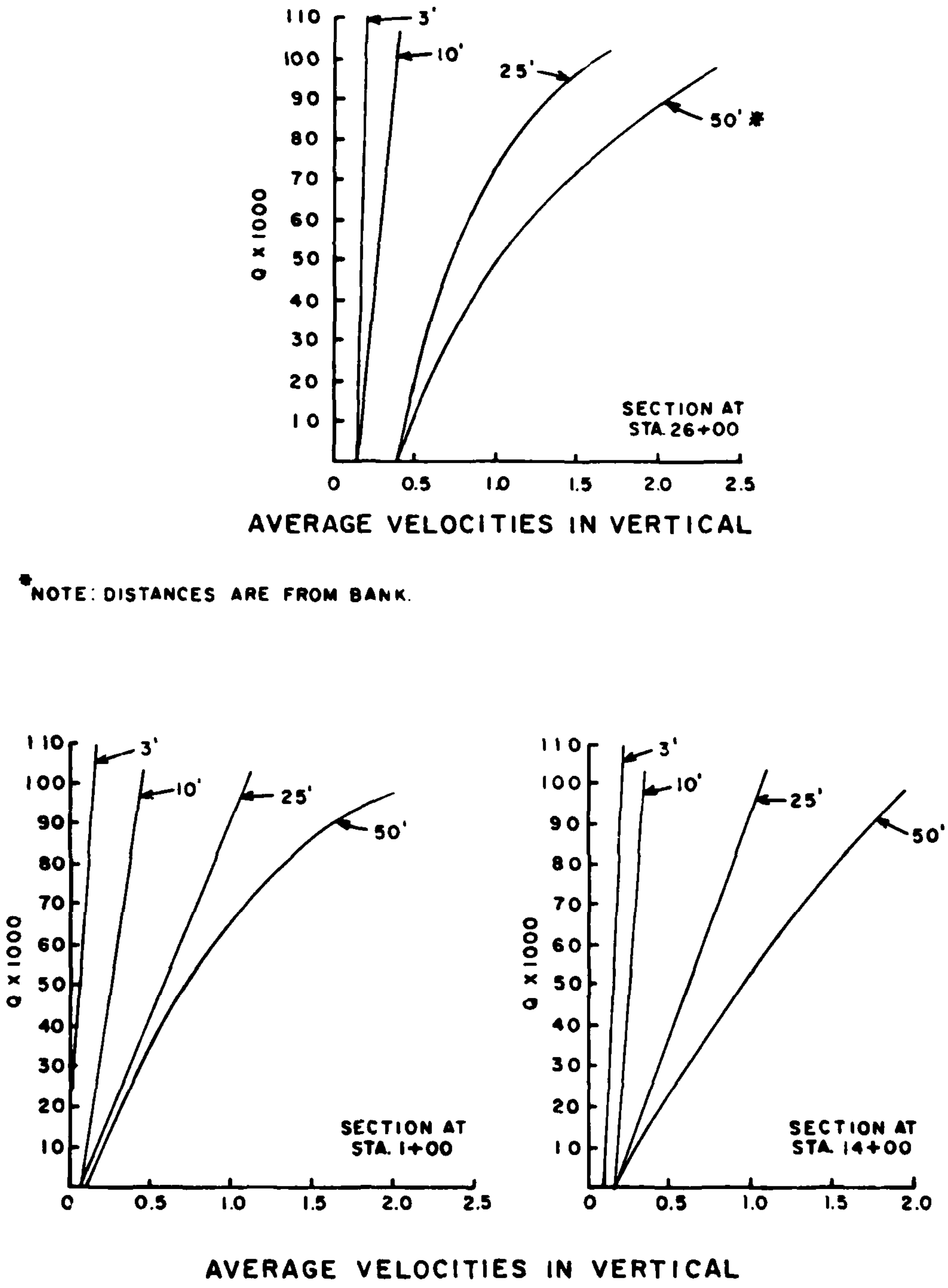
HYDROGRAPHS
MOUNDSVILLE, W. VA.
SITE
OHIO RIVER

PLATE 6



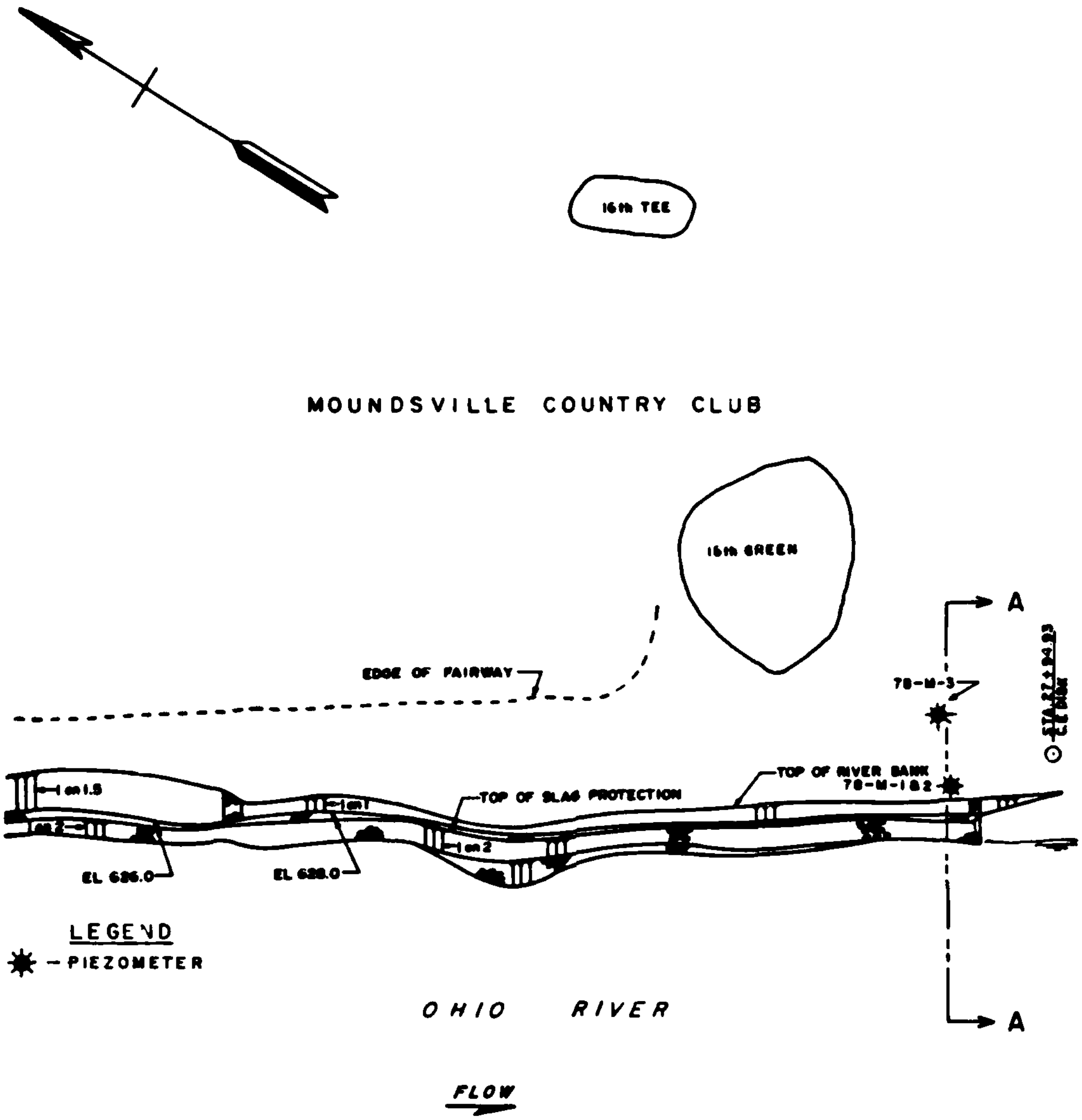
CHANNEL CROSS SECTIONS
MOUNDSVILLE, W. VA.
SITE
OHIO RIVER

PLATE 7



VELOCITY DISTRIBUTIONS
MOUNDSVILLE, W. VA.
SITE
OHIO RIVER

PLATE 8



GENERAL PLAN

SCALE: 1" = 100'

PIEZOMETER LOCATIONS
MOUNDSVILLE, W. VA.
SITE
OHIO RIVER

PLATE 9

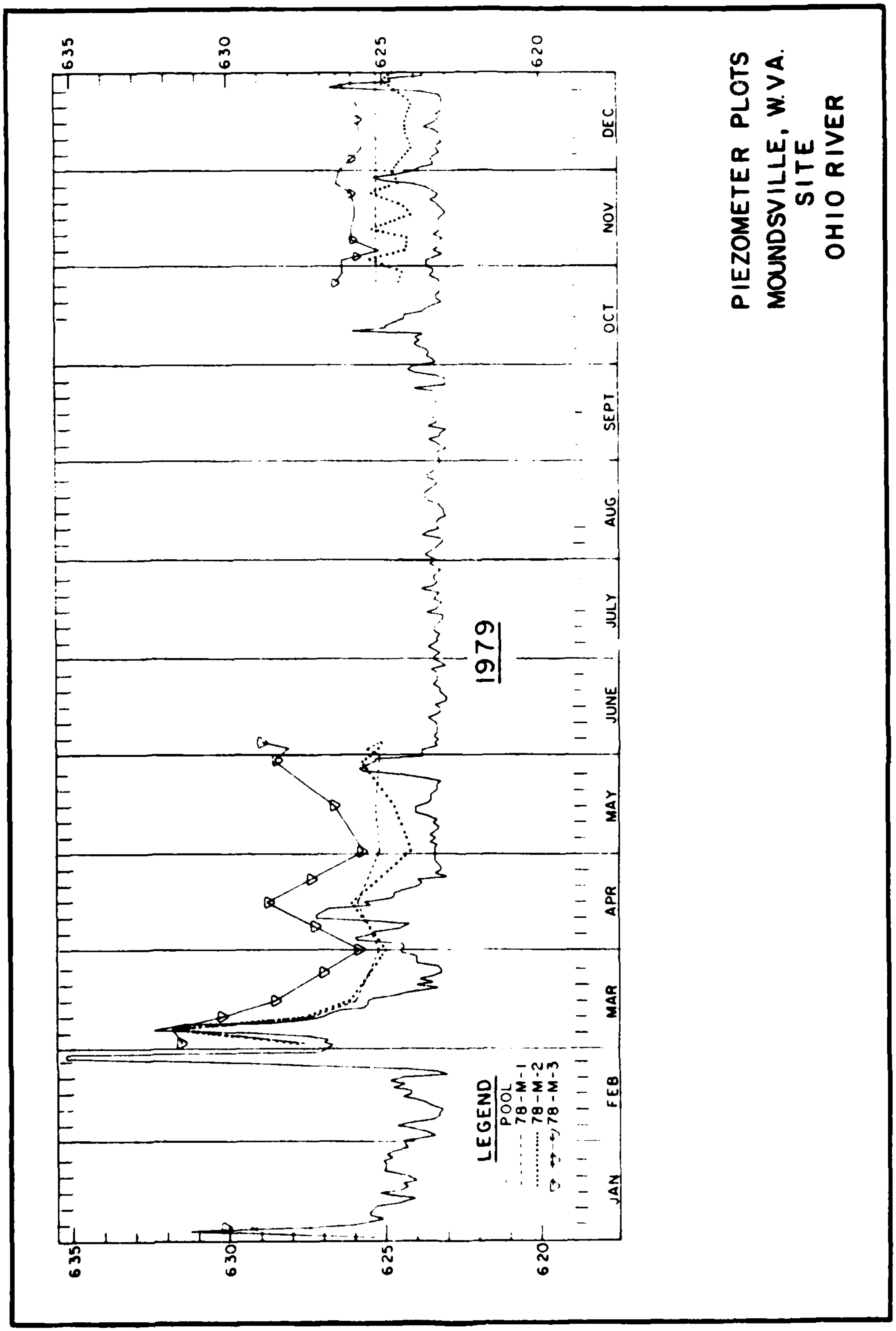
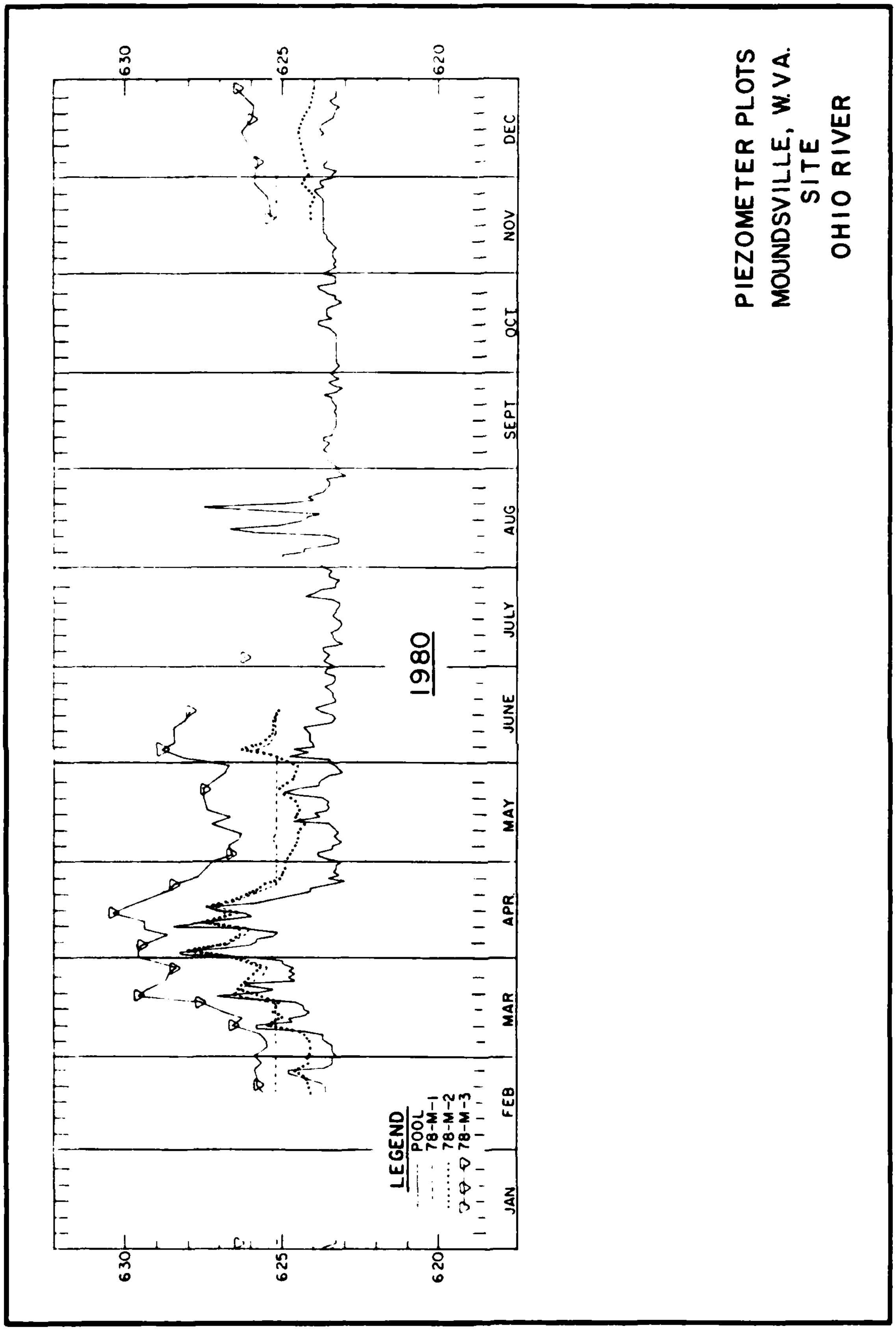

PIEZOMETER PLOTS
MOUNDSVILLE, W.VA.
SITE
OHIO RIVER
1979
LEGEND
POOL
78-M-1
78-M-2
78-M-3
JAN
FEB
MAR
APR
MAY
JUNE
JULY
AUG
SEPT
OCT
NOV
DEC
635
630
625
620

PLATE 10



PIEZOMETER PLOTS
MOUNDSVILLE, W.VA.
SITE
OHIO RIVER
1980
LEGEND
POOL
78-M-1
78-M-2
78-M-3
JAN
FEB
MAR
APR
MAY
JUNE
JULY
AUG
SEPT
OCT
NOV
DEC
630
625
620

PLATE 11

78-M-1 & 2

Location	Direction of hole from vertical	Date hole	Hole No.	Size and type of bit or sampler
STA. 27+50, 19 Feet Right	0°	Started 6 OCT 1978; Completed 10 OCT 1978	78-M-1 & 2	Roller Bit; 2-in O.D. Split Spoon; 140-lb Hammer - 30-in Drop

Piezometer tip	Elevation	Depth	LL	PL	W%	Blows per 0.5 feet	Legend	Classification of materials (Description)	Sample No.	Gravel	Sand	Fines	Remarks
	634.9	0.0						TOPSOIL					TOP OF HOLE
	634.4	0.5			DAMP	4-5 7-CO		Sandy SILT, brown	1				
	632.4	2.5			MOIST	3-4 6-CO		same	2				
	630.4	4.5			MOIST	2-2 2-CO		same	3				
	628.4	6.5			MOIST	2-2 3-CO		same	4				
	626.4	8.5			41.6	WEIGHT OF HAMMER	ML	Sandy SILT, brown w tr clay	5	*0	30	70	
1 →	625.5	9.4											
	624.4	10.5			MOIST	2-2 3-CO		Silty CLAY, brown, firm w tr fine sand	6				
	622.4	12.5			MOIST	3-4 6-CO		same	7				
	620.4	14.5				3-4 6-CO		NO RECOVERY	8				
	618.4	16.5			26.9	2-3 5-CO	SM	Silty SAND, brown, firm w tr clay	9	*0	52	48	
2 →	617.4	17.5											
	616.4	18.5				1-1 2-CO		NO RECOVERY	10				
	614.4	20.5		NP	30.0	1-1 2-CO	SM	Sandy SILT, brown, firm w tr clay, tr organic matter, sand fine	11	*0	32	68	
	612.4	22.5			MOIST	3-5 5-CO		Silty sandy CLAY, gray, firm	12				
	610.4	24.5				WEIGHT OF HAMMER			13				
	608.4	26.5			24.7	3-3 4-CO	SM	Silty SAND, brown, firm w tr clay	14	*0	56	44	
	606.4	28.5			WET	WOH - 3 4 - CO		SAND, brown and gray	15				
	604.4	30.5			WET	3-3 4-CO		Clayey silty SAND, brown, firm	16				
	602.4	32.5			WET	4-5 7-CO		Clayey silty SAND, gray, firm w tr organic matter	17				
	600.4	34.5				14-80/0.2		same	18				
	599.7	35.2				CO							
	598.4	36.5			WET	25-35 20-CO		SAND and GRAVEL, gray, loose	19				
	596.4	38.5				10-14 14-CO		GRAVEL, gray and brown	20				
	594.4	40.5				16-21 35-CO		NO RECOVERY	21				
	592.4	42.5			WET	23-33 32-CO		SAND and GRAVEL, brown, loose	22				
	590.4	44.5			WET	23-40 24-CO		SAND and GRAVEL, black, loose	23				
	588.4	46.5			WET	10-12 17-CO		SAND and GRAVEL, brown & gray, loose	24				
	586.4	48.5											BOTTOM OF HOLE

78-M-3

Location	Direction of hole from vertical	Date hole	Hole No.	Size and type of bit or sampler
STA 27+50, 20 Feet Left	0°	Started 11 OCT 1978; Completed 11 OCT 1978	78-M-3	Roller Bit; 2-in O.D. Split Spoon; 140-lb Hammer - 30-in Drop

Piezometer tip	Elevation	Depth	LL	PL	W%	Blows per 0.5 feet	Legend	Classification of materials (Description)	Sample No.	Gravel	Sand	Fines	Remarks
	635.5	0.0				CO							TOP OF HOLE
	635.0	0.5			MOIST	6-10 11-CO		Sandy SILT, brown, semi-firm	1				
	633.0	2.5			MOIST	7-11 15-CO		same	2				
	631.0	4.5			MOIST	6-10 11-CO		Sandy silty CLAY, brown, semi-firm	3				
	629.0	6.5			18.7	8-11 15-CO	SM	Sandy SILT, brown, sand fine	4	*0	20	80	
	627.0	8.5				5-6 8-CO		NO RECOVERY	5				
	625.0	10.5				2-3 5-CO		NO RECOVERY	6				
	623.0	12.5		NP	29.6	1-2 3-CO	SM	Silty SAND, brown, loose	7	*0	82	18	
	621.0	14.5			WET	1-2 3-CO		same	8				
	619.0	16.5		NP	20.4	WOH-1 2	ML	Silty SAND, brown, loose, tr clay	9	*0	45	55	
3 →	618.9	16.6											
	617.5	18.0											BOTTOM OF HOLE

LEGEND

→ - INDICATES PIEZOMETER TIP ELEVATION
CLAY - FIELD CLASSIFICATION
<u>CLAY</u> - LABORATORY CLASSIFICATION
* - ACTUAL GRADATION

STANDARD ABBREVIATIONS USED

W% - WATER CONTENT
PL - PLASTIC LIMIT
LL - LIQUID LIMIT
F.W. - FREE WATER
G.W. - GROUND WATER
MP - MEDIUM PLASTICITY
LP - LOW PLASTICITY
MHP - MEDIUM HIGH PLASTICITY
NP - NON-PLASTIC

GEOLOGIC ABBREVIATIONS

ANG - ANGULAR
FRAGS - FRAGMENTS
USC - UNIFIED SOILS CLASSIFICATION
CO - CLEAN OUT
D - DRILLED
EST - ESTIMATED
w - WITH
br - BROWN
gr - GRAY
tr - TRACE

PIEZOMETER BORING LOGS
MOUNDSVILLE, W.VA.
SITE
OHIO RIVER

PLATE 12

AUGUST 1972

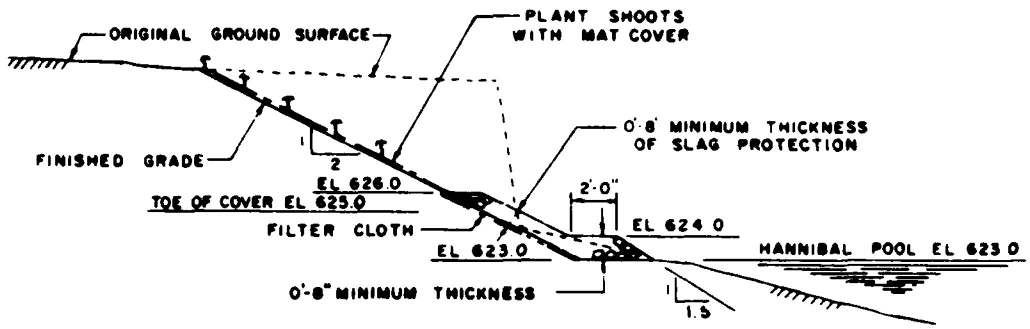
AUGUST 1972

4 JUNE 1976

4 JUNE 1976

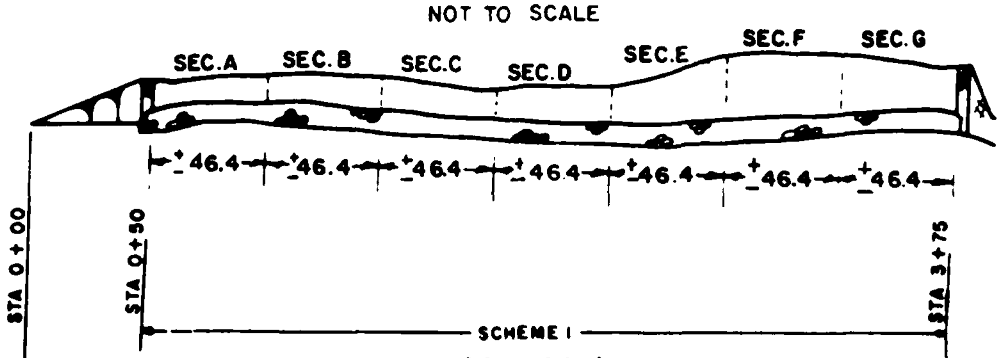
SITE PRECONSTRUCTION PHOTOS
MOUNDSVILLE, W.VA.
SITE
OHIO RIVER

PLATE 13



TYPICAL SECTION

(STA. 0+50 TO STA 3+75)
NOT TO SCALE



(PLAN)

OHIO RIVER

FLOW

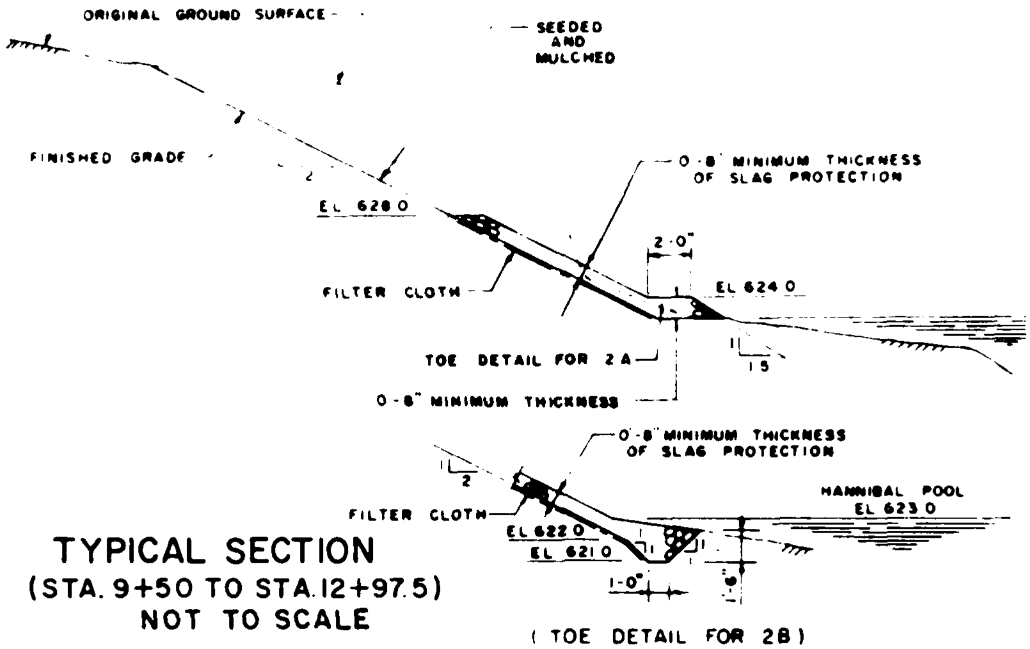
NOT TO SCALE

PLANT LIST

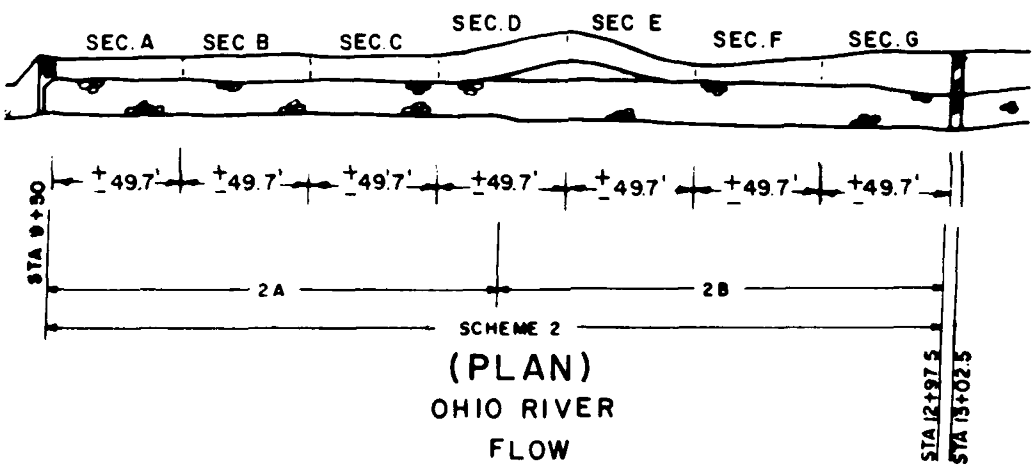
SEC.	BOTANICAL NAME	COMMON NAME
	SHRUBS	
A	SALIX PURPUREA	PURPLE OSIER WILLOW
B	CORNUS AMOMUM	SILKY DOGWOOD
C	CORNUS SIRICEA	RED OSIER DOGWOOD
D	MYRICA PENSYLVANICA	NORTHERN BAYBERRY
E	VACCINIUM ANGUSTIFOLIUM	LOWBUSH BLUEBERRY
F	VIBURNUM DENTATUM	ARROWWOOD VIBURNUM
G	ALNUS RUGOSA	SPECKLED ALDER
H	SPIRAEA SALICIFOLIA	WILLOW SPIREA

SCHEME I
MOUNDSVILLE, W. VA. SITE
OHIO RIVER

PLATE 14



TYPICAL SECTION
(STA. 9+50 TO STA. 12+97.5)
NOT TO SCALE



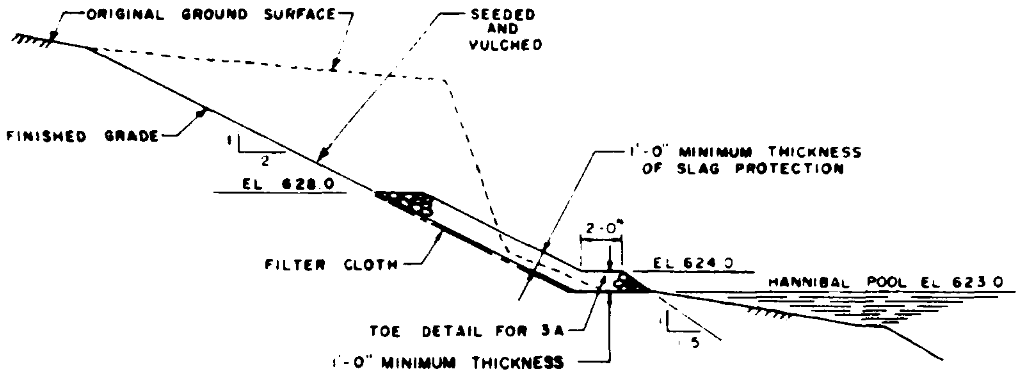
(PLAN)
OHIO RIVER
FLOW
NOT TO SCALE

PLANT LIST

SEC	BOTANICAL NAME	COMMON NAME	LBS/AC
A	PHALARIS ARUNDINACEA	REED CANARY GRASS	17
B	LOTUS CORNICULATUS	BIRDSFOOT TREFOIL	9
C	BROMUS INERMIS	SMOOTH BROMEGRASS	17
D	FESTUCA ARUNDINACEA	TALL FESCUE (KY 31-ALTA)	20
E	CORONILLA VARIA "PENNGIFT"	CROWN VETCH	10
F	LESPEDEZA CUNEATA	LESPEDEZA SERICEA	20
G	PHALARIS ARUNDINACEA	REED CANARY GRASS	25
	AGROSTIS ALBA	RED TOP	5
	LOTUS CORNICULATUS	BIRDSFOOT TREFOIL	10

SCHEME 2
MOUNDSVILLE, W. VA.
SITE
OHIO RIVER

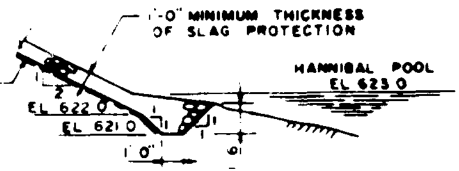
PLATE 15



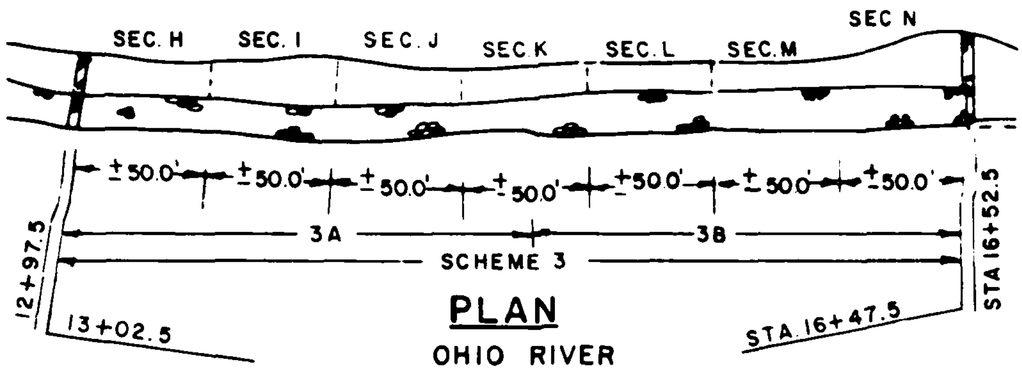
TYPICAL SECTION

STA 13+02.5 TO STA. 16+47.5

NOT TO SCALE



(TOE DETAIL FOR 3B)



PLAN

OHIO RIVER

NOT TO SCALE

PLANT LIST

SEC	BOTANICAL NAME	COMMON NAME	LBS/AC.
H	FESTUCA ARUNDINACEA	TALL FESCUE	30
	AGROSTIS ALBA	REDTOP	5
	LOTUS CORNICULATUS	BIRDSFOOT TREFOIL	10
I	LOTUS CORNICULATUS	BIRDSFOOT TREFOIL	4
	FESTUCA ARUNDINACEA	TALL FESCUE (KY 31-ALTA)	20
	CORONILLA VARIA "PENNGIFT"	CROWN VETCH	6
J	FESTUCA ARUNDINACEA	TALL FESCUE (KY 31-ALTA)	30
	CORONILLA VARIA "PENNGIFT"	CROWN VETCH	10
K	LOTUS CORNICULATUS	BIRDSFOOT TREFOIL	8
	BROMUS INERMIS	SMOOTH BROMEGRASS	
L	FESTUCA ARUNDINACEA	TALL FESCUE (KY 31-ALTA)	35
	AGROSTIS ALBA	REDTOP	5
M	LOTUS CORNICULATUS	BIRDSFOOT TREFOIL	8
	PHALARIS ARUNDINACEA	REED CANARY GRASS	8
N	LESPEDEZA CUNEATA	LESPEDEZA SERECIA	10
	PHALARIS ARUNDINACEA	REED CANARYGRASS	15

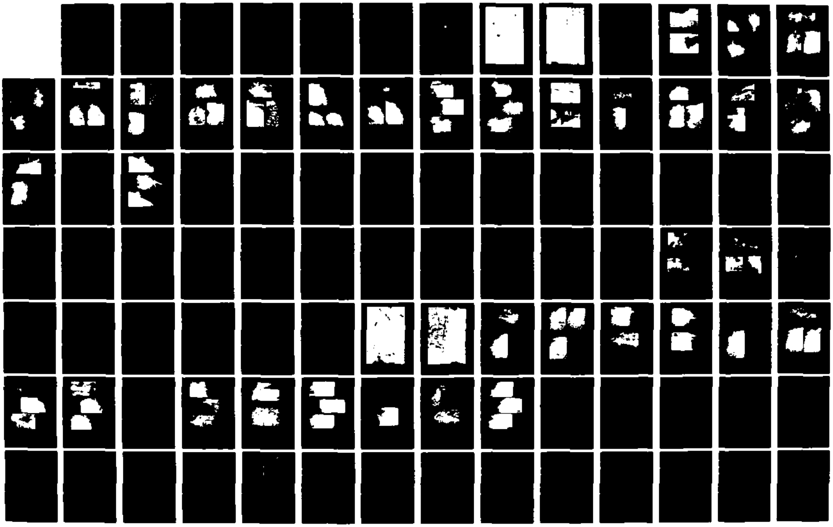
SCHEME 3
MOUNDSVILLE, W VA.
SITE
OHIO RIVER

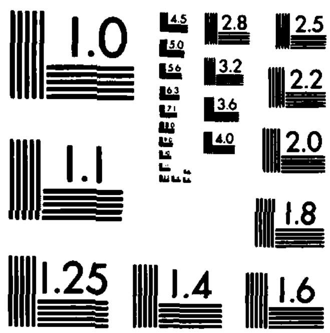
PLATE 16

AD-A121 134 THE STREAMBANK EROSION CONTROL EVALUATION AND DEMONSTRATION ACT OF 1974 S..(U) ARMY ENGINEER WATERWAYS EXPERIMENT STATION VICKSBURG MS HYDRA..

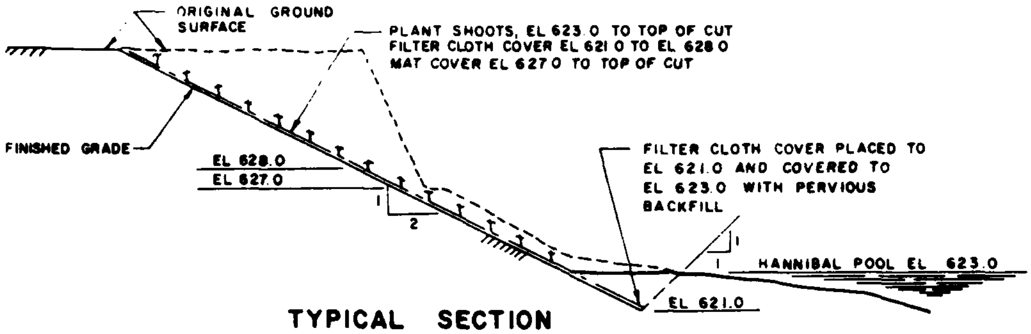
2/4

UNCLASSIFIED M P KEOWN ET AL. DEC 81 WES/TR/H-77-9-APP-D F/G 13/2 NL

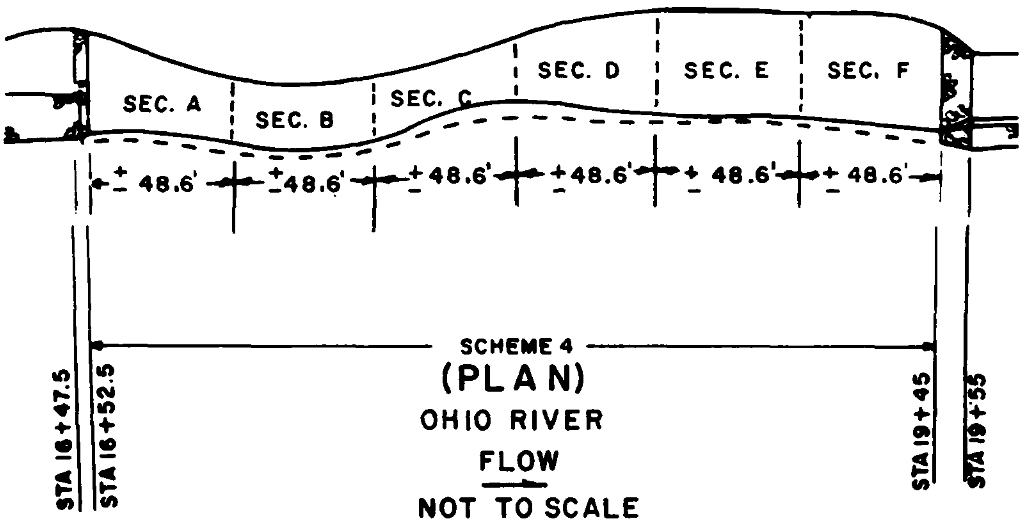




MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A



TYPICAL SECTION
(STA. 16+52.5 TO STA. 19+45)
NOT TO SCALE



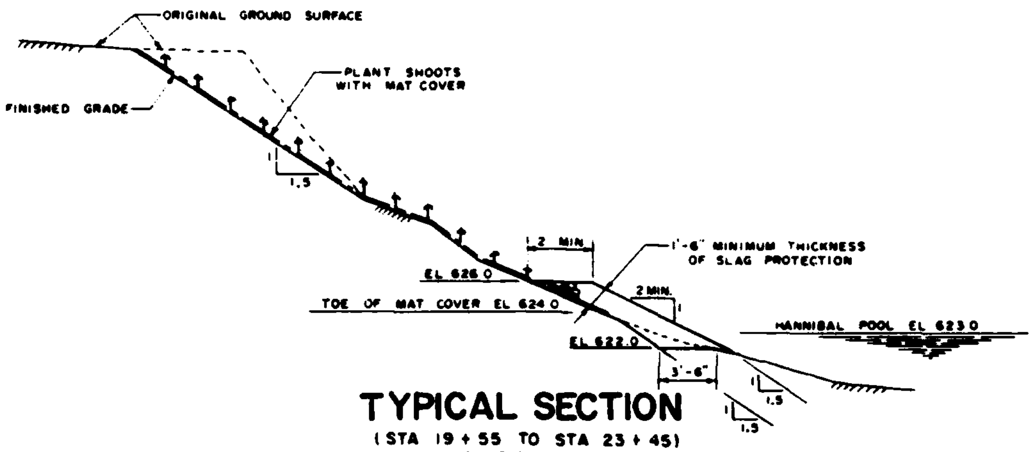
SCHEME 4
(PLAN)
OHIO RIVER
FLOW
NOT TO SCALE

PLANT LIST

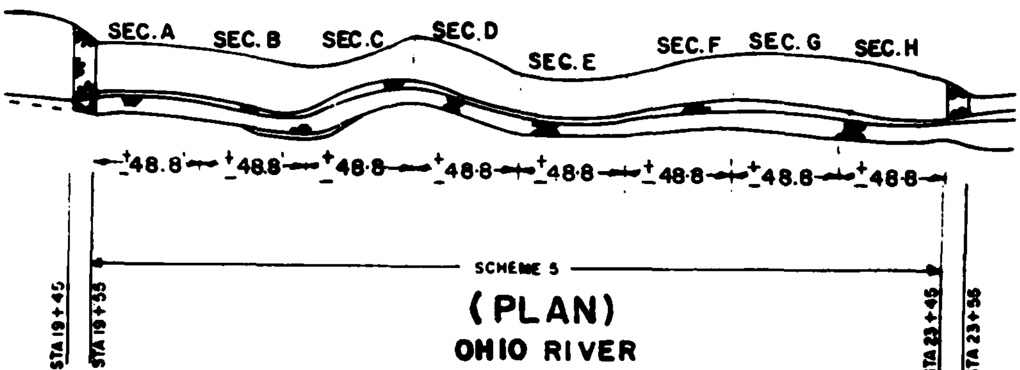
SEC.	BOTANICAL NAME	COMMON NAME
	SHRUBS	
A	SALIX PURPUREA	PURPLE OSIER WILLOW
B	CORNUS AMOMUM	SILKY DOGWOOD
C	CORNUS SIRICEA	RED OSIER DOGWOOD
D	MYRICA PENSYLVANICA	NORTHERN BAYBERRY
E	VACCINIUM ANGUSTIFOLIUM	LOWBUSH BLUEBERRY
F	VIBURNUM DENTATUM	ARROWWOOD VIBURNUM
G	ALNUS RUGOSA	SPECKLED ALDER
H	SPIRAEA SALICIFOLIA	WILLOW SPIREA

SCHEME 4
MOUNDSVILLE, W. VA.
SITE
OHIO RIVER

PLATE 17



TYPICAL SECTION
(STA 19+55 TO STA 23+45)
NOT TO SCALE



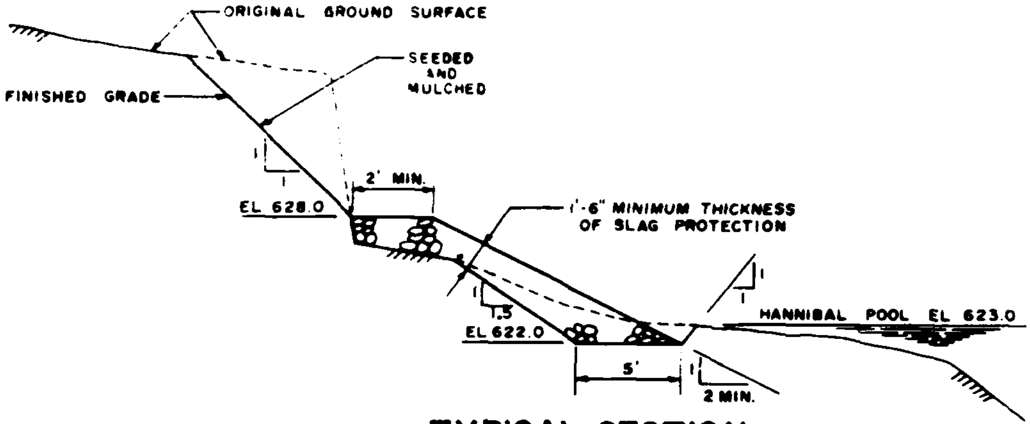
(PLAN)
OHIO RIVER
FLOW
NOT TO SCALE

PLANT LIST

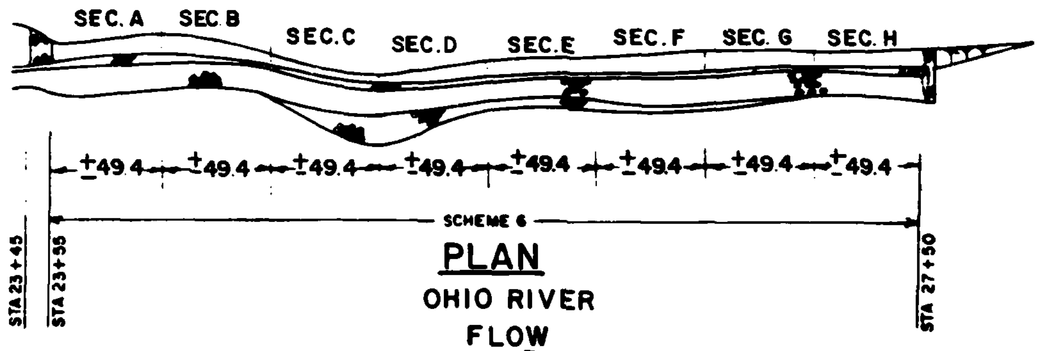
SEC.	BOTANICAL NAME	COMMON NAME
	SHRUBS	
A	SALIX PURPUREA	PURPLE OSIER WILLOW
B	CORNUS AMOMUM	SILKY DOGWOOD
C	CORNUS SIRICEA	RED OSIER DOGWOOD
D	MYRICA PENSYLVANICA	NORTHERN BAYBERRY
E	VACCINIUM ANGUSTIFOLIUM	LOWBUSH BLUEBERRY
F	VIBURNUM DENTATUM	ARROWWOOD VIBURNUM
G	ALNUS RUGOSA	SPECKLED ALDER
H	SPIRAEA SALICIFOLIA	WILLOW SPIREA

SCHEME 5
MOUNDSVILLE, W.VA.
SITE
OHIO RIVER

PLATE 18



TYPICAL SECTION
(STA 23 + 55 TO STA 27 + 50)
NOT TO SCALE



PLAN
OHIO RIVER
FLOW
NOT TO SCALE

PLANT LIST

SEC	BOTANICAL NAME	COMMON NAME	LBS/AC.
	LEGUMES & GRASSES		
A	PHALARIS ARUNDINACEA	REED CANARY GRASS	17
B	LOTUS CORNICULATUS	BIRDSFOOT TREFOIL	9
C	BROMUS INERMIS	SMOOTH BROMEGRASS	17
D	FESTUCA ARUNDINACEA	TALL FESCUE(KY 31-ALTA)	20
E	CORONILLA VARIA "PENNGIFT"	CROWN VETCH	10
F	LESPEDEZA CUNEATA	LESPEDEZA SERICEA	20
G	PHALARIS ARUNDINACEA AGROSTIS ALBA LOTUS CORNICULATUS	REED CANARY GRASS RED TOP BIRDSFOOT TREFOIL	25 5 10
H	FESTUCA ARUNDINACEA AGROSTIS ALBA LOTUS CORNICULATUS	TALL FESCUE REDTOP BIRDSFOOT TREFOIL	30 5 10

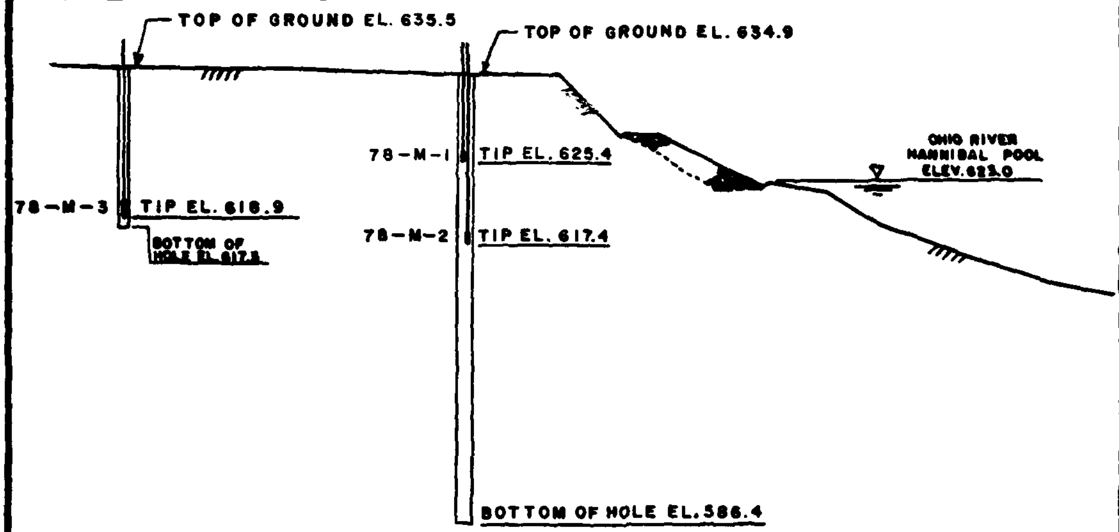
SCHEME 6
MOUNDSVILLE, W. VA. SITE
OHIO RIVER

PLATE 19

PARAMETER	ITEM	FREQUENCY
GEOMETRY	1. Overbank crossections from baseline to 50 ft. riverward of water's edge at 50 ft. intervals	Biyearly
	2. Full channel crossections	Once
	3. Ground photos from fixed reference points	Monthly
	4. Controlled vertical low level aerial photos	Annual
CLIMATE	1. Air temp., precip., wind direction & velocity (weather station)	Continuous
	2. Ice conditions, snow cover noted from visual observations	As available
HYDRAULICS	1. River stage record from staff gage at sta. 16+45	Twice daily by observer
	2. Velocity measurements A. <u>Total River Width</u>: Observations across at 0.2, 0.6, 0.8 and depth w/directional meter w/at least 30 verticals to be taken at sta. 1+00, 3+00, 8+00, 14+00, 18+00, 22+00, 26+00, and 29+00 B. <u>Bank</u>: Observations out from bank 3 ft., 6 ft., 10 ft., 25 ft., and 50 ft. at sta. 1+00, 3+00, 4+50, 6+00, 8+00, 10+00, 12+00, 14+00, 16+00, 18+00, 20+00, 22+00, 24+00, 26+00	3 times (at low, med. & high flows)
	3. River traffic (though observation and lock records)	As available
STREAM-BANK PROTECTION	1. Monitor dimensional changes of marked structural & vegetal units through photos & manual measurements	Monthly
	2. Observe durability of marked units of structural material (qualitative)	Monthly
	3. Observe condition of marked plants	Monthly
	4. Record initiation and measure progression of failures in bank protection	Monthly
GEOLOGY AND SOILS	1. Material properties testing	Annual
	2. Observation of groundwater level piezometers (3)	Semi-weekly

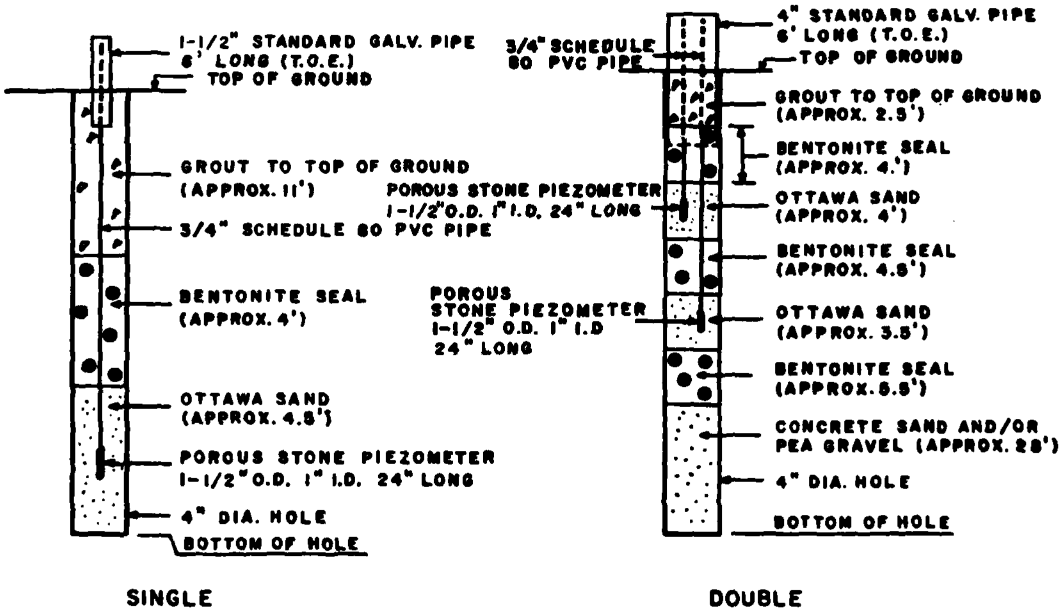
MONITORING PROGRAM
MOUNDSVILLE, W. VA. SITE
OHIO RIVER

PLATE 20



SECTION A-A

NOT TO SCALE

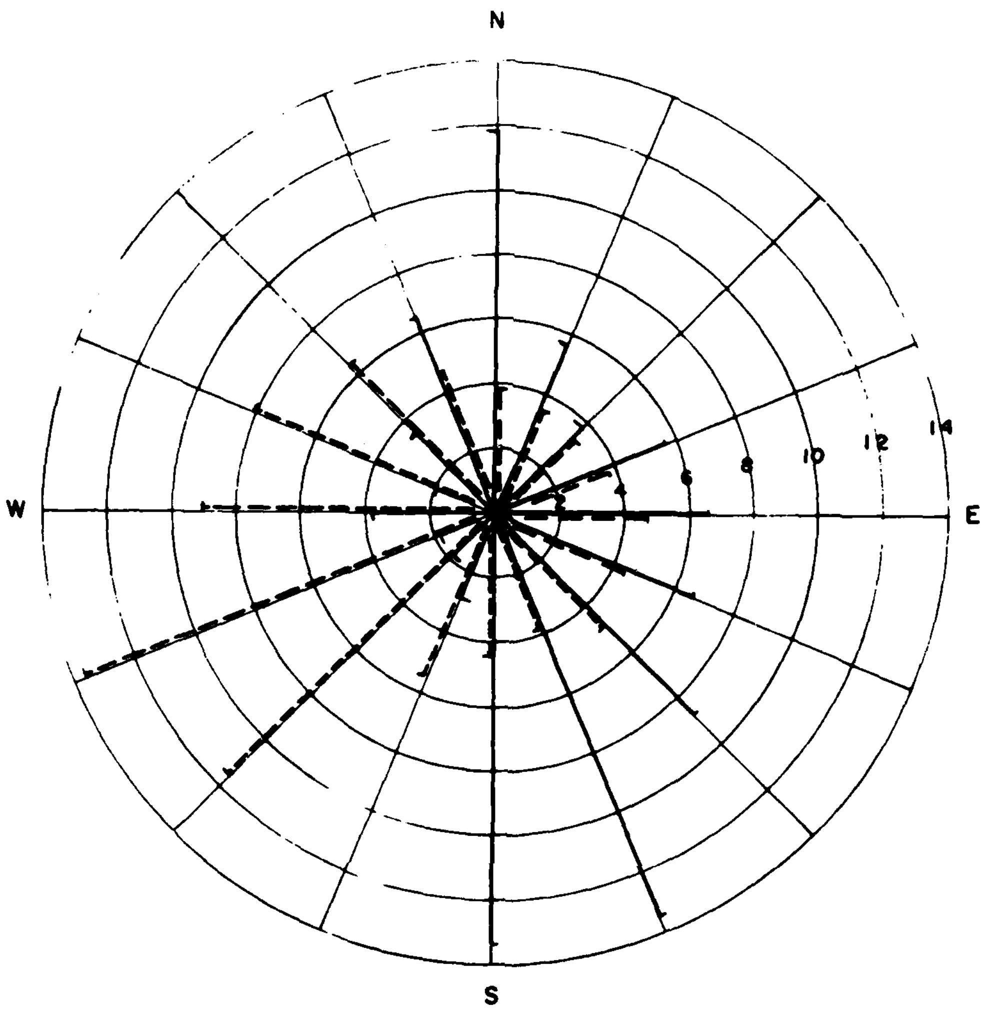


PIEZOMETER DETAILS

NOT TO SCALE

PIEZOMETER INSTALLATION
MOUNDSVILLE, W.VA.
SITE
OHIO RIVER

PLATE 21



DIRECTIONAL PERCENT OF TIME

——— MOUNDSVILLE COUNTRY CLUB (JAN. 79–APR. 80)
- - - - - GREATER PITTSBURGH I.A.P. (1945–1965)

WIND ROSE
MOUNDSVILLE, W. VA.
SITE
OHIO RIVER

PLATE 22

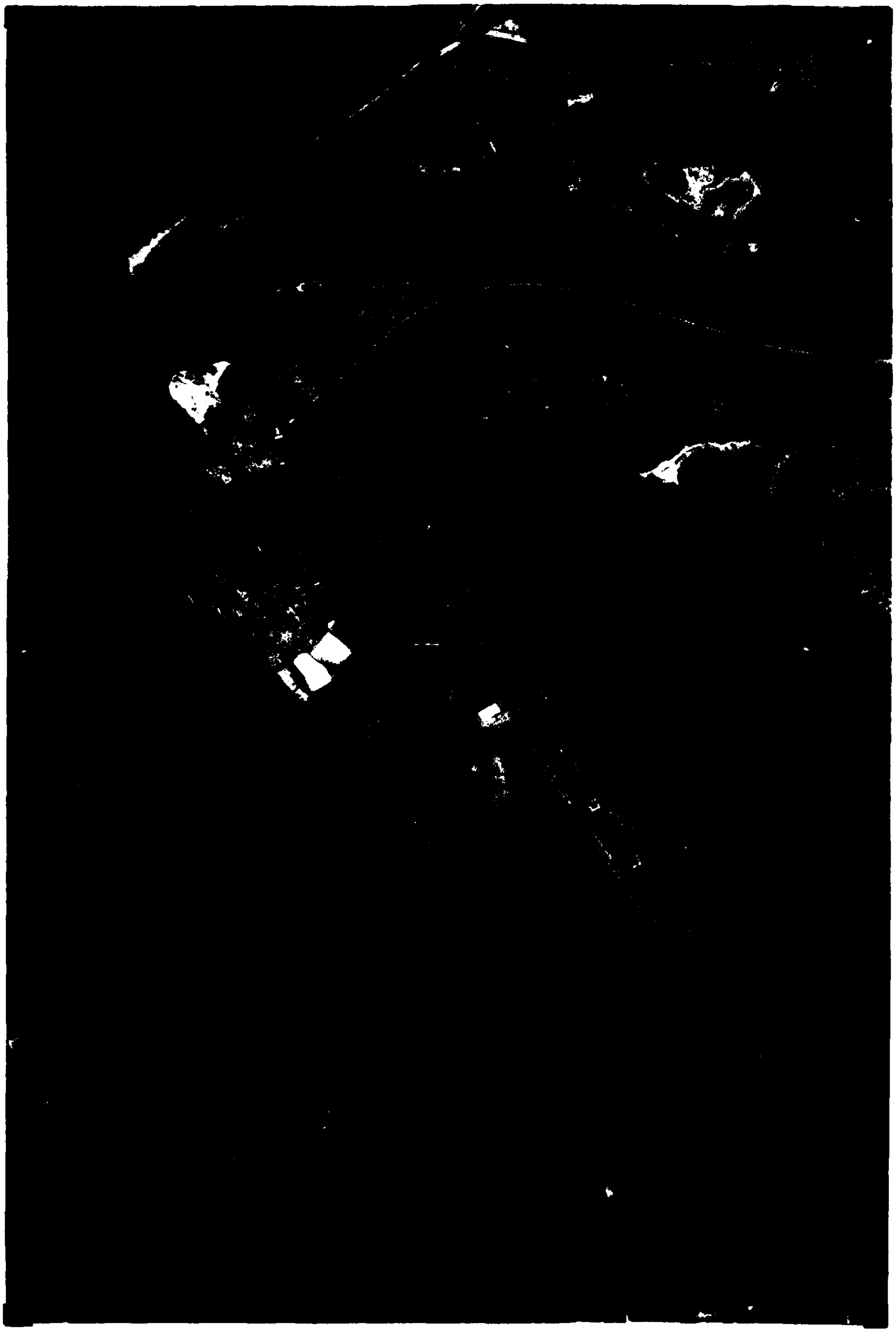


PLATE 23

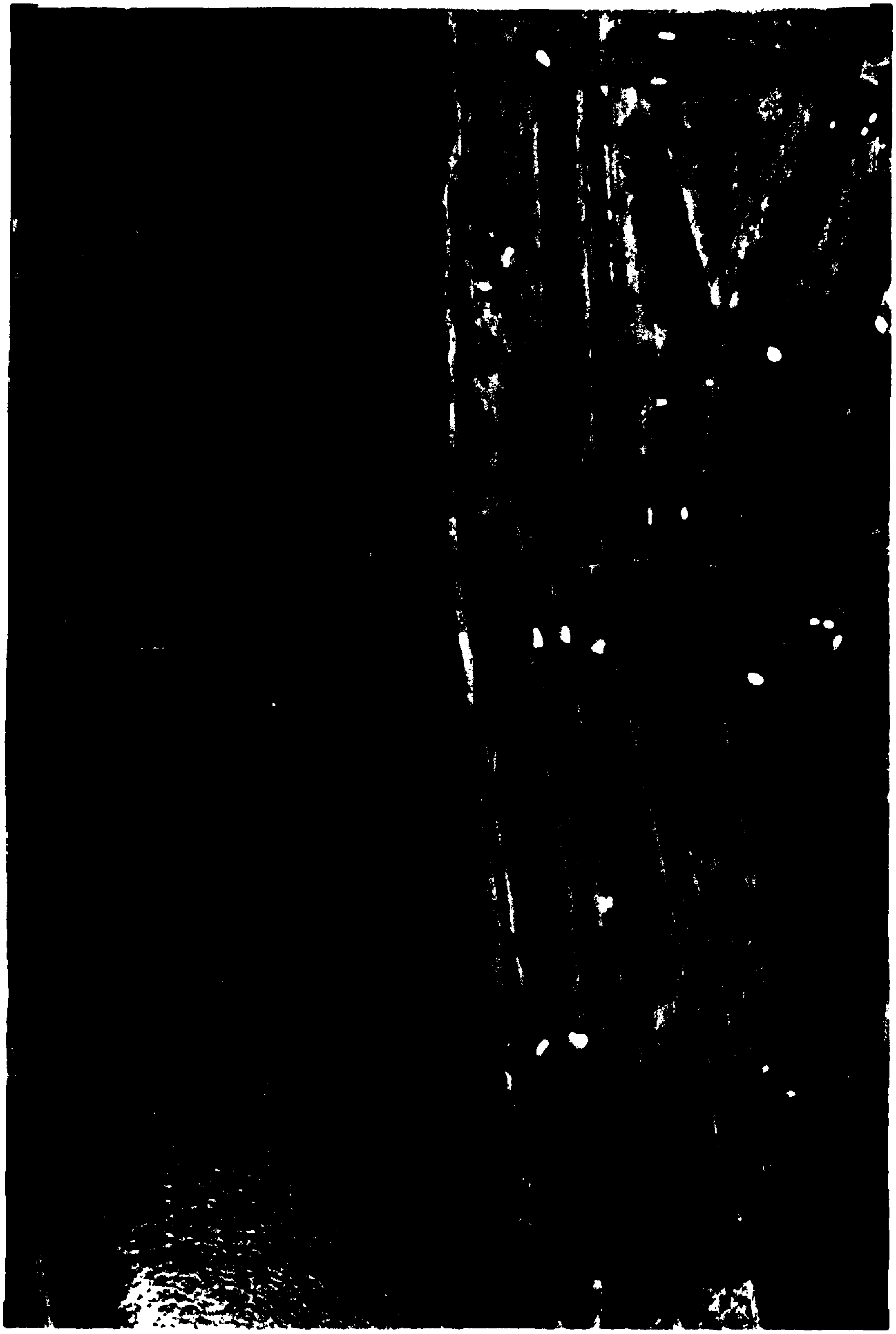


PLATE 24

SCHEME (1)	SECTION (2)	INITIAL SPACING (3)	% OF PLANTED SECTION GROWING (4)	(PER SQ FT) DENSITY INCREASE OR DECREASE (5)	CONDITION OF PLANTS (6)	COMPARATIVE VALUE (7)	DATE PLANTED MAY 77 CURRENT DATE MAY 80 (8) REMARKS (9)
1	A	2'X2' O.C.	40	DECREASE	FAIR	115	Lower half washed out
	B	2'X2' O.C.	30	DECREASE	FAIR	105	Overrun with weeds
	C	2'X2' O.C.	90	INCREASE	EX.	265	Withstood erosion well
	D	2'X2' O.C.	50	SAME	GOOD	175	Withstanding erosion
	E	2'X2' O.C.	40	DECREASE	POOR	90	
	F	2'X2' O.C.	90	INCREASE	GOOD	240	Withstood high water
	G	2'X2' O.C.	5	DECREASE	POOR	55	
2	A	17#/ACRE	80	INCREASE	EX.	255	Crown Vetch invading area
	B	9#/ACRE	—	—	—	0	Completly taken over – Vetch
	C	17#/ACRE	5	DECREASE	POOR	55	Crown Vetch takeover
	D	20#/ACRE	20	DECREASE	FAIR	95	Eroded down bank
	E	10#/ACRE	80	INCREASE	GOOD	230	Crowding out weeds
	F	20#/ACRE	1	DECREASE	POOR	56	Overrun by Crown Vetch
	G	3 PLANT MIX	a. 50 b. & c. 0	INCREASE	EX.	225	CROWN VETCH INVADING NO REDTOP OR TREFOIL
3	H	3 PLANT MIX	5	DECREASE	POOR	55	Crown Vetch invading
	I	3 PLANT MIX	30	SAME	a. GOOD b. & c. POOR	130	CROWN VETCH DOING WELL FESCUE & TREFOIL DOING POORLY
	J	2 PLANT MIX	70	INCREASE	a. POOR c. GOOD	195	FESCUE DOING POORLY CROWN VETCH DOING WELL
	K	2 PLANT MIX	5	DECREASE	POOR	55	Overrun with Crown Vetch
	L	2 PLANT MIX	—	—	—	0	Crown Vetch and weeds
	M	2 PLANT MIX	90	INCREASE	a. — b. EX.	265	TREFOIL – POOR OR NONE CROWN VETCH – VERY GOOD
	N	2 PLANT MIX	90	INCREASE	a. POOR b. GOOD	215	LESPEDEZA – POOR CANARY REEDGRASS – VERY GOOD
4	A	2'X2' O.C.	80	SAME	GOOD	205	Dense grass cover
	B	2'X2' O.C.	50	DECREASE	FAIR	125	
	C	2'X2' O.C.	80	SAME	EX.	230	Very vigorous
	D	2'X2' O.C.	70	SAME	GOOD	195	
	E	2'X2' O.C.	20	DECREASE	POOR	70	
	F	2'X2' O.C.	80	SAME	FAIR	180	
5	A	2'X2' O.C.	50	SAME	GOOD	175	Invaded with large weeds
	B	2'X2' O.C.	50	SAME	GOOD	175	Choked with weeds
	C	2'X2' O.C.	90	INCREASE	EX.	265	
	D	2'X2' O.C.	10	DECREASE	FAIR	85	Only present at bottom
	E	2'X2' O.C.	—	—	—	0	Plants eroded or slid down
	F	2'X2' O.C.	80	INCREASE	GOOD	230	Invaded by Blackberry
	G	2'X2' O.C.	10	DECREASE	POOR	60	Bad slide area
	H	2'X2' O.C.	50	SAME	GOOD	150	Heavy weeds
6	A	17#/ACRE	10	DECREASE	POOR	60	Heavy weeds (Thistle)
	B	9#/ACRE	5	DECREASE	POOR	55	Invaded with various weeds &
	C	17#/ACRE	5	DECREASE	POOR	55	Same as above Crown Vetch
	D	20#/ACRE	5	DECREASE	POOR	80	Same as above
	E	10#/ACRE	50	INCREASE	GOOD	200	GRASS & WEED CUTTINGS DUMPED ON SECTION
	F	20#/ACRE	5	DECREASE	POOR	55	INVADED BY CROWN VETCH & WEEDS SLIDE AREA
	G	3 PLANT MIX	80	SAME	a. GOOD b. & c. POOR	155	Canarygrass doing excellently
	H	3 PLANT MIX	5	DECREASE	POOR	55	Bad slide

COMPARATIVE VALUE RATIONALE. IN ORDER TO GIVE EACH PLANTED SECTION A VALUE TO INDICATE THE DEGREE OF PLANT SUCCESS, THE VALUES LISTED IN COLUMNS 4, 5 & 6 ARE COMBINED TO FORM A TOTAL COMPARATIVE VALUE AS SHOWN IN COLUMN 7. A COMPARATIVE VALUE OF 300 IS MAXIMUM. A VALUE OF 0 IS MINIMUM, INDICATING PLANT FAILURE IN ALL CATEGORIES.

THE VALUE OF COLUMN 4 IS EQUAL TO THE PERCENT SHOWN, AND REPRESENTS THE PERCENT OF THE SECTION COVERED BY PLANTS.

COLUMN 5 VALUES:

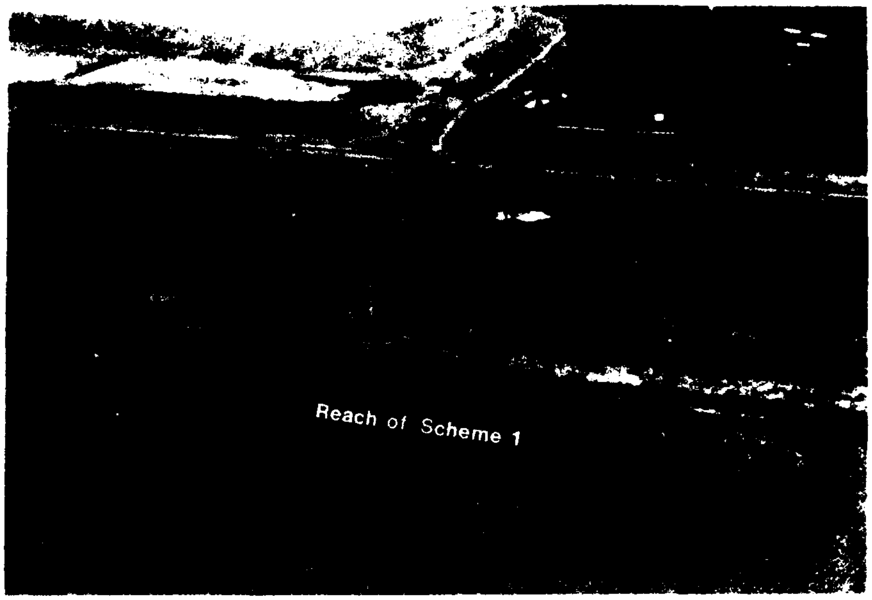
EXCEPTIONAL INCREASE OR VERY GOOD GERMINATION	100
INCREASE OR GOOD GERMINATION	75
SAME OR POOR GERMINATION	50
DECREASE OR VERY POOR GERMINATION	25
BLANK SPACE OR 0	0

COLUMN 6 VALUES

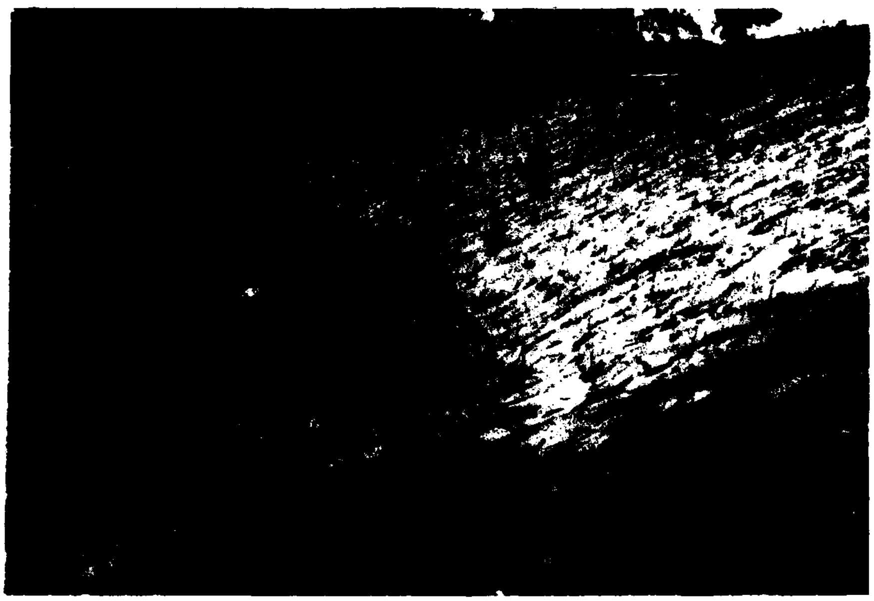
EX (EXCELLENT)	100
GOOD	75
FAIR	50
POOR	25
BLANK SPACE OR 0	0

PLANT MATERIAL EVALUATION
MOUNDSVILLE, WVA.
SITE
OHIO RIVER

PLATE 25



PRECONSTRUCTION AERIAL VIEW
17 APRIL 1974



LOOKING UPSTREAM FROM STATION 3+80
12 MAY 1977

SCHEME 1 PHOTOS
MOUNDSVILLE, W. VA.
SITE
OHIO RIVER

PLATE 26

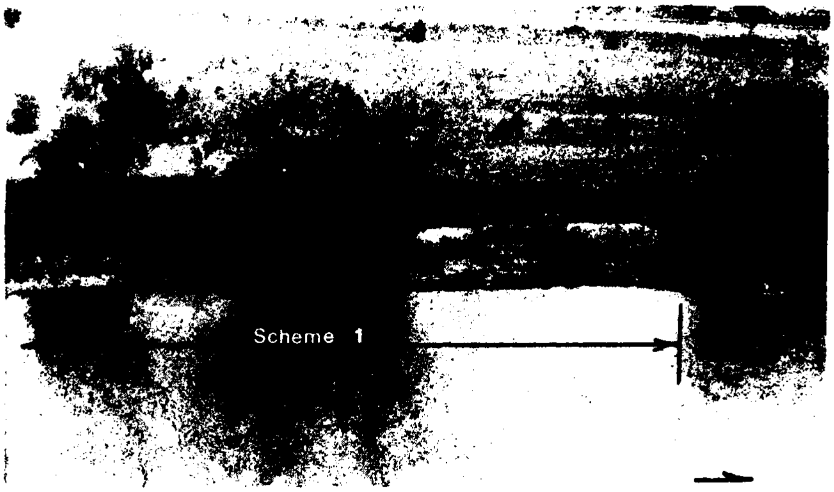
LOOKING UPSTREAM
FROM STATION 3+80
30 SEPTEMBER 1977

LOOKING UPSTREAM
FROM STATION 3+80
24 MARCH 1978

LOOKING UPSTREAM
FROM STATION 3+80
2 MARCH 1979

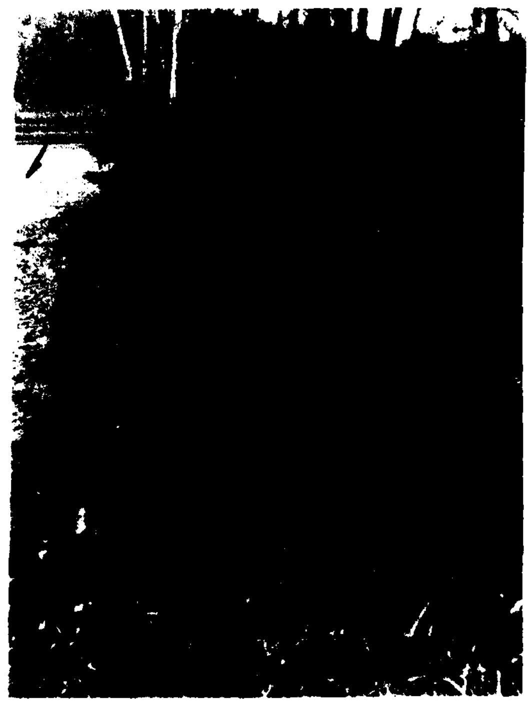
SCHEME 1 PHOTOS
MOUNDSVILLE, W. VA.
SITE
OHIO RIVER

PLATE 27



AERIAL VIEW
15 MAY 1979

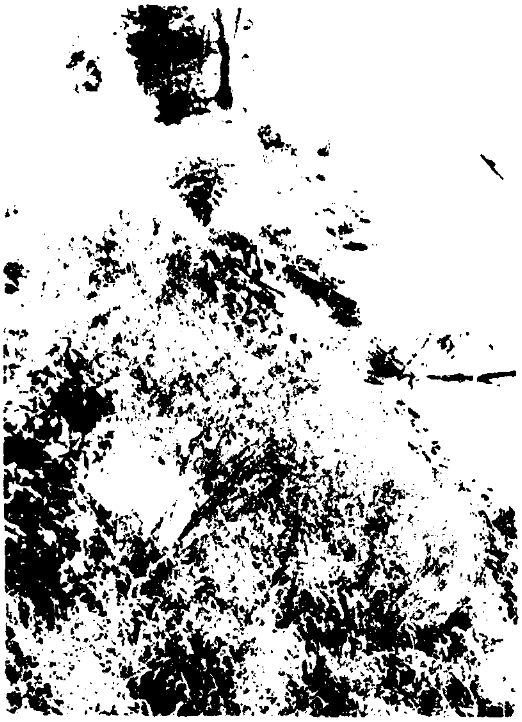
LOOKING UPSTREAM FROM
STATION 3+80
8 APRIL 1980



LOOKING UPSTREAM FROM
STATION 3+80
3 DECEMBER 1980

SCHEME 1 PHOTOS
MOUNDSVILLE, W. VA.
SITE
OHIO RIVER

PLATE 28



LOOKING DOWNSTREAM
FROM STATION 5+00
30 SEPTEMBER 1977

LOOKING DOWNSTREAM
FROM STATION 5+00
24 MARCH 1978

LOOKING DOWNSTREAM
FROM STATION 5+00
2 MARCH 1979

RUBBLE ZONE PHOTOS
MOUNDSVILLE, W. VA.
SITE
OHIO RIVER

PLATE 29

AERIAL VIEW
15 MAY 1979

LOOKING DOWNSTREAM
FROM STATION 5+00
8 APRIL 1980

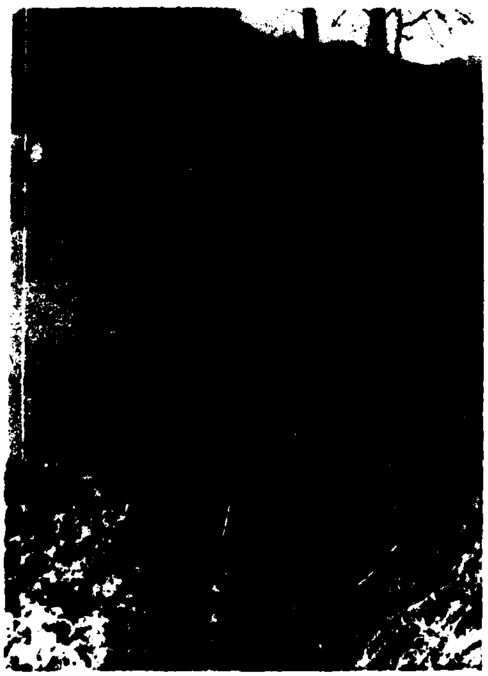
LOOKING DOWNSTREAM
FROM STATION 5+00
3 DECEMBER 1980

RUBBLE ZONE PHOTOS
MOUNDSVILLE, W.VA.
SITE
OHIO RIVER

PLATE 30

LOOKING UPSTREAM FROM
STATION 13+00
6 JUNE 1977

LOOKING UPSTREAM FROM
STATION 13+00
30 SEPTEMBER 1977



LOOKING UPSTREAM FROM
STATION 13+00
24 MARCH 1978

SCHEME 2 PHOTOS
MOUNDSVILLE, W. VA.
SITE
OHIO RIVER

PLATE 31

LOOKING UPSTREAM FROM STATION 13+00
NOTE HIGH WATER DAMAGE TO UPPER BANK
2 MARCH 1979

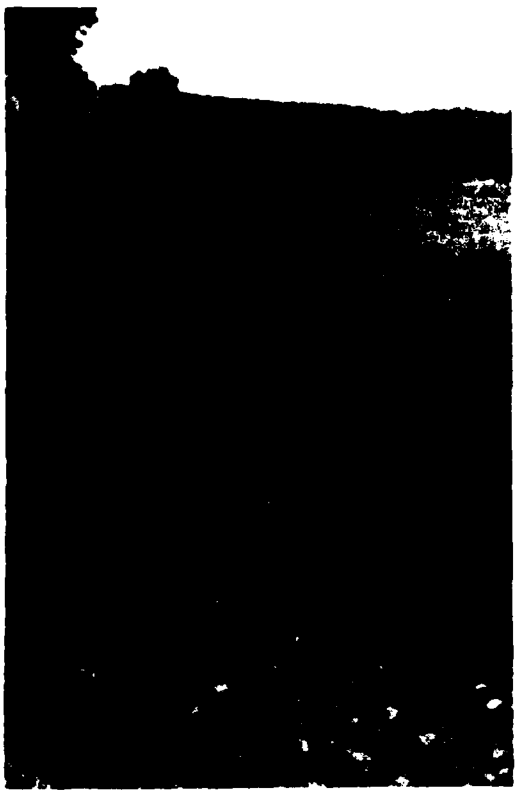
LOOKING UPSTREAM FROM
STATION 13+00
8 APRIL 1980

LOOKING UPSTREAM FROM
STATION 13+00
3 DECEMBER 1980

SCHEME 2 PHOTOS
MOUNDSVILLE, W. VA.
SITE
OHIO RIVER

PLATE 32

DURING CONSTRUCTION
LOOKING UPSTREAM
FROM STATION 16+25
9 DECEMBER 1976



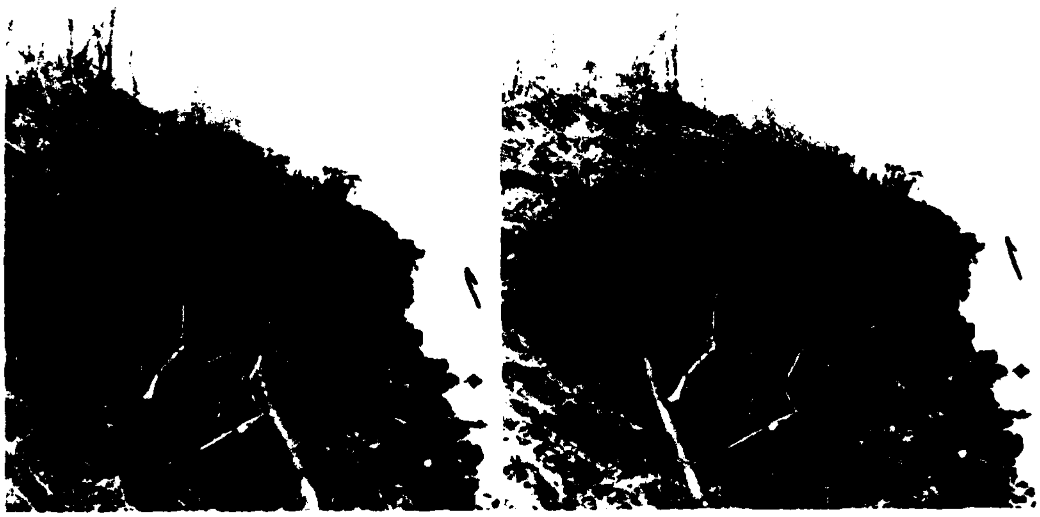
LOOKING DOWNSTREAM FROM
STATION 13+00
6 JUNE 1977

LOOKING DOWNSTREAM FROM
STATION 13+00
30 SEPTEMBER 1977

SCHEME 3 PHOTOS
MOUNDSVILLE, W. VA.
SITE
OHIO RIVER

PLATE 33

LOOKING DOWNSTREAM FROM
STATION 13+00, NOTE HIGH
WATER DAMAGE TO UPPER BANK
24 MARCH 1978



DOWNSTREAM STEROSCOPIC VIEW
FROM STATION 13+00, NOTE HIGH
WATER DAMAGE TO UPPER BANK
2 MARCH 1979

SCHEME 3 PHOTOS
MOUNDSVILLE, W. VA.
SITE
OHIO RIVER

PLATE 34

AERIAL VIEW
15 MAY 1979

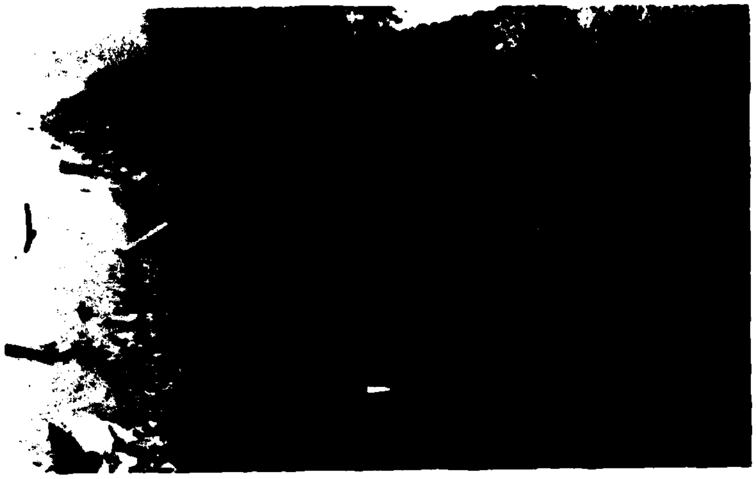
LOOKING DOWNSTREAM FROM
STATION 13+00
8 APRIL 1980

LOOKING DOWNSTREAM FROM
STATION 13+00
3 DECEMBER 1980

SCHEME 3 PHOTOS
MOUNDSVILLE, W. VA.
SITE
OHIO RIVER

PLATE 35

LOOKING UPSTREAM
FROM STATION 19+50
6 JUNE 1977



LOOKING UPSTREAM
FROM STATION 19+50
22 JULY 1977

LOOKING UPSTREAM
FROM STATION 19+50
30 SEPTEMBER 1977

SCHEME 4 PHOTOS
MOUNDSVILLE, W. VA.
SITE
OHIO RIVER

PLATE 36

LOOKING UPSTREAM
FROM STATION 19+50
24 MARCH 1978

LOOKING UPSTREAM
FROM STATION 19+50
2 MARCH 1979

LOOKING UPSTREAM
FROM STATION 19+50
3 DECEMBER 1980

SCHEME 4 PHOTOS
MOUNDSVILLE, W. VA.
SITE
OHIO RIVER

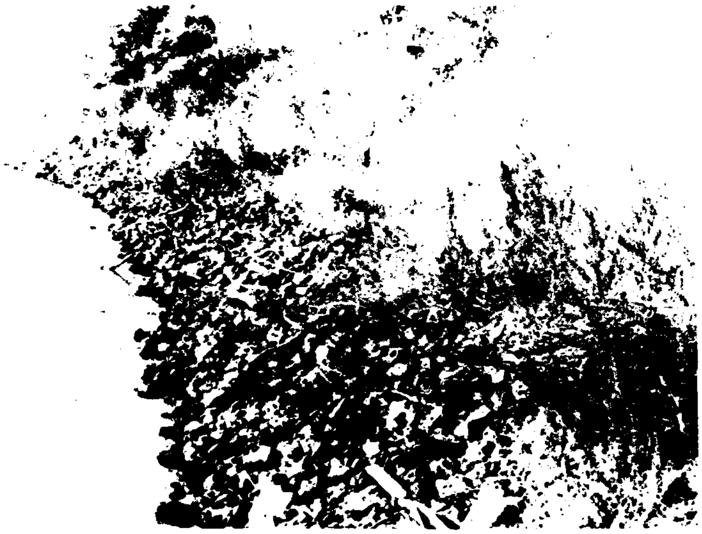
PLATE 37

PRECONSTRUCTION
17 APRIL 1974

LOOKING UPSTREAM FROM STATION 23+50
29 APRIL 1977

SCHEME 5 PHOTOS
MOUNDSVILLE, W. VA.
SITE
OHIO RIVER

PLATE 38



LOOKING UPSTREAM
FROM STATION
22+75
30 SEPTEMBER 1977

LOOKING UPSTREAM FROM
STATION 22+75
24 MARCH 1978

SCHEME 5 PHOTOS
MOUNDSVILLE, W. VA.
SITE
OHIO RIVER

PLATE 39

LOOKING UPSTREAM
FROM STATION 22+75
2 MARCH 1979

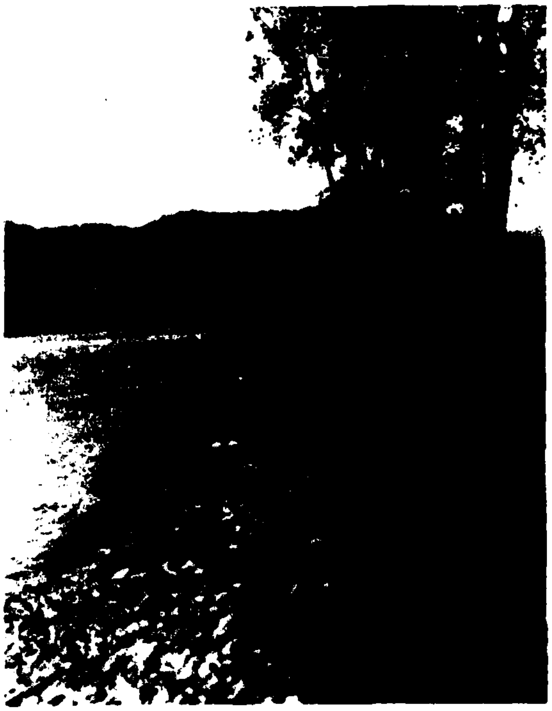
LOOKING UPSTREAM FROM
STATION 22+75
8 APRIL 1980

LOOKING UPSTREAM FROM
STATION 22+75
3 DECEMBER 1980

SCHEME 5 PHOTOS
MOUNDSVILLE, W. VA.
SITE
OHIO RIVER

PLATE 40

DURING CONSTRUCTION
LOOKING UPSTREAM FROM
STATION 27+50
10 DECEMBER 1976



LOOKING UPSTREAM FROM
STATION 27+50
6 JUNE 1977

SCHEME 6 PHOTOS
MOUNDSVILLE, W. VA.
SITE
OHIO RIVER

PLATE 41

LOOKING UPSTREAM FROM
STATION 27+50
30 SEPTEMBER 1977

LOOKING UPSTREAM FROM
STA 27+50, NOTE HIGH
WATER DAMAGE TO UPPER
BANK. 24 MARCH 1978

LOOKING UPSTREAM
FROM STATION 27+50
NOTE HIGH WATER
DAMAGE TO UPPER
BANK. 2 MARCH 1979

SCHEME 6 PHOTOS
MOUNDSVILLE, W. VA.
SITE
OHIO RIVER

PLATE 42

LOOKING UPSTREAM FROM STATION 27+50
8 APRIL 1980

LOOKING UPSTREAM FROM
STATION 27+50
3 DECEMBER 1980

SCHEME 6 PHOTOS
MOUNDSVILLE, W. VA.
SITE
OHIO RIVER

PLATE 43

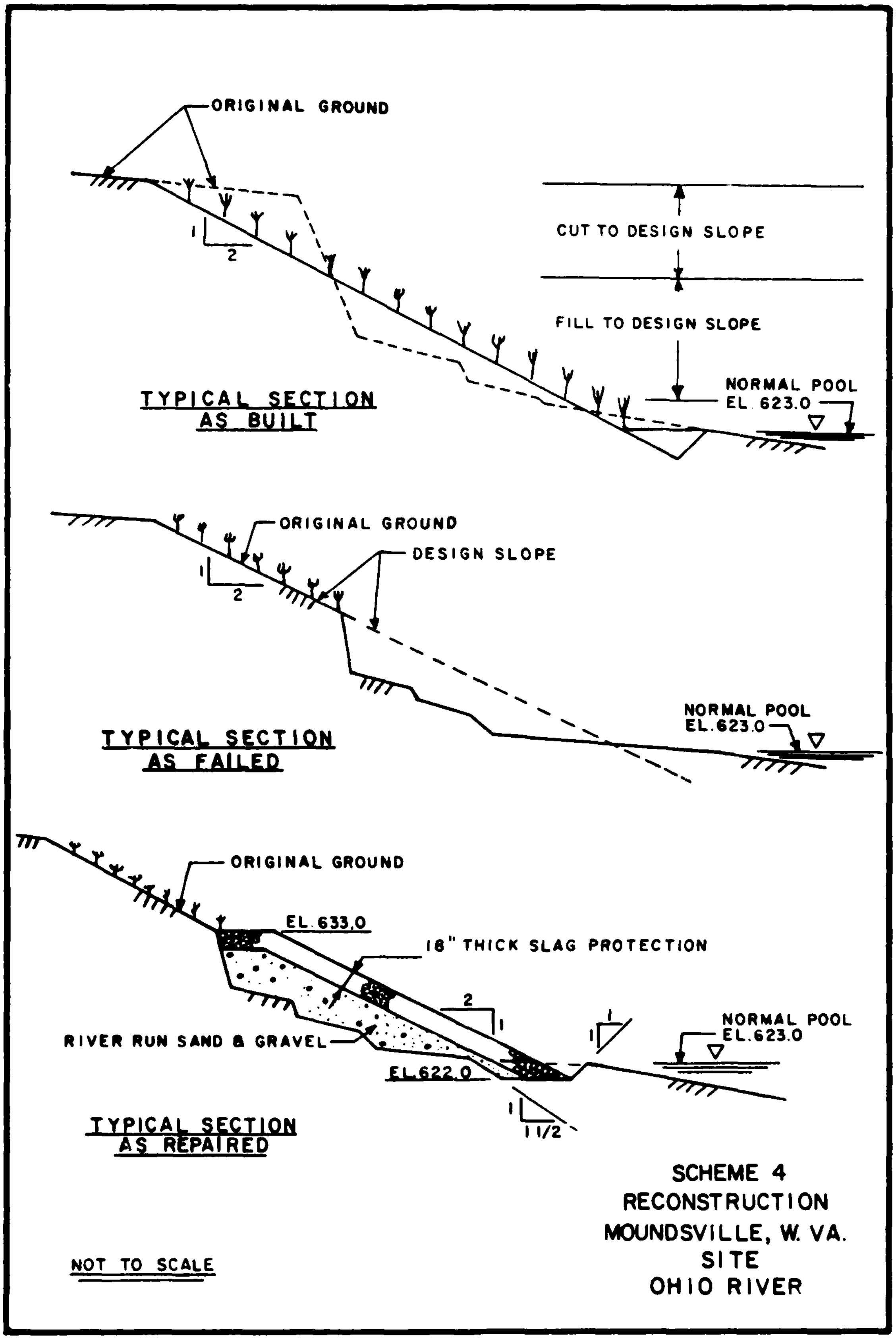

ORIGINAL GROUND
CUT TO DESIGN SLOPE
FILL TO DESIGN SLOPE
NORMAL POOL
EL. 623.0
TYPICAL SECTION
AS BUILT
ORIGINAL GROUND
DESIGN SLOPE
NORMAL POOL
EL.623.0
TYPICAL SECTION
AS FAILED
ORIGINAL GROUND
EL.633.0
18" THICK SLAG PROTECTION
RIVER RUN SAND & GRAVEL
EL.622.0
NORMAL POOL
EL.623.0
TYPICAL SECTION
AS REPAIRED
NOT TO SCALE
SCHEME 4
RECONSTRUCTION
MOUNDSVILLE, W. VA.
SITE
OHIO RIVER

PLATE 44

POST CONSTRUCTION
22 JULY 1977

SCHEME FAILURE
23 MAY 1978

SCHEME
REHABILITIZED
8 AUGUST 1978

SCHEME 4 RECONSTRUCTION PHOTOS
MOUNDSVILLE, W. VA.
SITE
OHIO RIVER

PLATE 45

OHIO RIVER
POWHATAN POINT, OHIO

Section 32 Program Streambank Erosion Control
Evaluation and Demonstration Act of 1974

OHIO RIVER AT POWHATAN POINT, OHIO
DEMONSTRATION PROJECT PERFORMANCE REPORT

I. INTRODUCTION

A. Project Name and Location: Powhatan Point, Demonstration Project, Ohio River - mile 109.8. Plate 1 shows the project location.

B. Authority. Streambank Erosion Control Evaluation and Demonstration Act of 1974, Section 32, P.L. 93-251.

C. Purpose and Scope. This report describes a bank erosion problem, the types of protection used, and a performance evaluation of a demonstration project on the Ohio River designed and monitored by the Pittsburgh District.

D. Problem Resume. The right bank of the Ohio River immediately downstream of the mouth of Captina Creek was subject to active erosion that was encroaching, in varying degrees, on 28 residential and small commercial properties.

II. HISTORICAL DESCRIPTION

A. Stream Description, General.

1. Topography. The Ohio River at the demonstration site drains an area of 25,500 square miles covering primarily Pennsylvania west of the Allegheny Mountains and extending into portions of Ohio, West Virginia, New York, and Maryland. Major tributaries are the Allegheny, Monongahela, and Beaver Rivers. The topography of the basin is characterized by mature development of the drainage systems within the Allegheny plateau physiographic province. From its origin at Pittsburgh the river descends 90 feet along a course of 109.8 miles to the demonstration site. Relief at the site is approximately 700 feet from the river to the top of the surrounding valley walls. The river flows south at the demonstration site following a sinuous course with curves

varying from 45 degrees to 180 degrees and radii of 1 to 2 miles. The natural stream gradient in this area is about 0.5 foot per mile. The valley floor averages about 0.6 of a mile in width. Stream bank heights average from 17 feet at Wheeling to several feet above normal pool at the Hannibal Lock and Dam. The Powhatan Point demonstration site is near the middle of a narrow alluvium terrace which extends along the river for 3 miles on the inside of a shallow southeastern bend.

2. Geology. The Ohio River throughout its course along the West Virginia-Ohio border has become entrenched in sedimentary strata of Pennsylvanian and Lower Permian Age. These strata are made up of interbedded sandstones, siltstones, clays, shales, limestones, and coals. The bedrock valley of the Ohio River contains an alluvial fill of outwash from the Wisconsin Continental Glacier. In the portion of the Ohio Valley within the study area, the alluvial fill is predominantly gravel, sand and gravel, and gravelly sand. Since the last glacial episode, the Ohio River has been cutting down through the alluvium with the formation of river terraces at various elevations in the Wisconsin fill and a well defined flood plain. In the study area, the Ohio River is still underlain by the Wisconsin alluvial fill to depths of 35 to 60 feet. A layer of fine grained alluvium, averaging 10 to 30 feet in thickness, has been deposited on the flood plain by inundations of Ohio River floodwaters.

The Ohio River channel has been shifting back and forth across the alluvium which fills the bedrock valley. The channel is thus frequently located asymmetrically on one side of the old bedrock valley. In these areas, one bank consists of the highly erodible flood plain deposits and the other consists of rock out-crops or colluvial soil which has accumulated through weathering and creep of the hillsides above. The colluvial soils are generally stiff to hard silty clays with angular rock fragments and little or no layering. These soils tend to resist erosion and seem to erode at a much slower rate than flood plain deposits.

The alluvial flood plain on which the Powhatan Point site is located is about 60 to 70 feet thick. Water wells drilled near the demonstration site show fine grained alluvium to depths of 30 to 40 feet underlain by sand and gravel to the top of bedrock.

3. Locality, Development, and Occupation. The Ohio River valley in the vicinity of the demonstration site has developed a diverse industrial character. Over the past several decades most of the broad agricultural bottoms have been acquired for industrial development. Within the Hannibal navigation pool the river valley contains several large cities and towns, including Wheeling, Moundsville, and New Martinsville in West Virginia, and Martins Ferry, Bellaire, and Shadyside in Ohio. Local industries include coal mining, steel, chemical and aluminum production, electric power generation, and a variety of light manufacturing. The river is paralleled by railroads and highways on both banks.

The Ohio River has been an important transportation artery since prehistory and has undergone navigation improvements since 1824 when Congress provided for removal of obstructions such as bars and snags. For many years river navigation was facilitated solely by open channel improvements. In addition to removal of channel obstructions, stone training dikes were constructed at various bars in order to constrict the channel and increase the scour of the river. The first movable dam on the Ohio River was located at Davis Island, 4.7 miles below Pittsburgh, and opened to commerce October 7, 1885. A system of locks and movable dams was eventually constructed along the entire Ohio River. In August 1917, Lock and Dam 14 was put into operation 4 miles downstream of the demonstration site. These early dams incorporated a navigable pass to provide a channel for open river navigation during periods of high flow. A series of wickets, heavy timber shutters, were raised to impound water as needed to maintain a navigation pool. When not required, the wickets would lie flat at such a depth as to offer no obstruction to free navigation through the pass. Replacement of these

original navigation dams with fixed, gated structures having higher lifts has been ongoing. In 1975, Hannibal Locks and Dam went into full operation and Locks and Dams 12, 13 and 14 were removed.

4. Hydrologic Characteristics. The Ohio River valley in the vicinity of the demonstration site is subject to a continental climate with high and low temperature extremes of 95 degrees to 105 degrees F., and -15 degrees to -25 degrees F. The mean annual temperature averages 50 degrees F. The growing season extends from late April to mid-October. Normal annual precipitation is approximately 40 inches per year. The flood of record occurred in March 1936 with a maximum discharge of 450,000 c.f.s. in the vicinity of the demonstration site. This flow exceeded the 500-year flood and, at the demonstration site, overtopped the bank by 12 feet. A stage frequency curve is shown on Plate 2. A one-year flood hydrograph is shown on Plate 3.

5. Existing Channel Conditions. The sinuosity of the channel was described in paragraph II.A.1. The channel location has been relatively stable within historical time. A discharge rating curve for the river at the site location is shown on Plate 2.

6. Environmental Considerations. A minor amount of farming is practiced in the few remaining undeveloped portions of the river valley. This is being accomplished under lease from the industries in the area who own these properties and are reserving them for future expansion of facilities. The steep hillsides adjacent to the valley floor are primarily undeveloped and consist of second growth woodlands. Within the flood plain, vegetation associated with farming and frequent site disturbance prevails. Along the river bottom land, silver maple and sycamore occur most frequently, while elm, cottonwood, buckeye and willow are present with somewhat reduced representation. On the hillsides and in areas of greater stability above ordinary high water, oaks, beech, red maple, ash, black cherry and walnut exist. Timber stands, adjacent to the river, are generally of low quality because of physical

damage caused by ice and floating debris during high water. Nails, spikes, eye bolts, cables and physical damage from river traffic are also evident in many specimens.

Both fish and wildlife resources of significance are found in the project area. Fishes include such species as channel catfish, carp, spotted bass, largemouth bass, smallmouth bass, white bass, pumpkinseed, bluegill, white crappie, shiners, perch, skipjacks, gizzard shad and golden redhorse. Excellent warm-water fisheries have developed at or near the mouths of several of the tributary streams. Wildlife resources also include a variety of species. Mourning doves, bobwhite quail and cottontail rabbits are present in the agricultural areas, while ruffed grouse and squirrels inhabit the uplands. White-tailed deer are present in the adjacent uplands and also range into the valley. The Ohio River also provides resting and feeding opportunities for several species of migratory waterfowl. Muskrat, mink, raccoon and fox are some of the fur animals in the area.

This reach of the river, as with the entire Ohio in general, is exposed to various types of pollution which tend to affect aquatic life and generally detract from the aesthetic value of the river. Excessive amount of organic matter, chemicals, sediment and colloidal particles contribute to the relatively poor water quality, with seasonal variations experienced as a result of changes in flow and temperature.

The use of steel furnace slag in demonstration schemes, which specify structural protection, may also result in a level of water quality degradation commensurate with the bulk chemical content of the slag and the availability of its chemical constituents to the Ohio River as a result of leaching and weathering. Fines may also enter the Ohio River as a result of slag erosion. Plate 4 provides a comparison of results of leachability tests performed on slag used at the demonstration site with Ohio River water quality near the Powhatan Point site and relevant water quality criteria and standards.

7. Environmental Effects. During the proposed work, disturbance of the river bed and bank would result in temporary, construction-related increases in turbidity and suspended matter in the Ohio River downstream of the project site, which would be confined to an approximate 45-day construction period. Grading and recontouring of the bank slope would result in the loss of established herbaceous and woody vegetation and exposure of disturbed soil to river currents and weathering. Filter cloth matting would aid in the retention of exposed soil prior to revegetation. The use of air-cooled basic oxygen furnace slag in schemes which specify structural protection may result in a level of water quality degradation commensurate with the bulk chemical content of the slag and the availability of its chemical constituents to the Ohio River as a result of leaching and weathering. However, the quantities of slag involved, weathering and aging of the slag surface and gradual revegetation would tend to minimize the level of chemical constituents leached from the slag. The required excavations would diminish habitat diversity within the riverine littoral region and along the protected shoreline, but would not result in the loss of significantly productive shallow water habitat or aquatic or terrestrial cover necessary to sustain a locally diverse fish or wildlife population.

Both short and long-term benefits would accrue as a result of the proposed action: (1) One or more optimum designs of bank protection would be determined as a result of periodic monitoring and studies of the relative durability of the various demonstration project schemes. (2) The proposed demonstration project schemes may collectively relieve the acute bank erosion problem at each of the proposed test sites.

B. Demonstration Project.

1. Hydrologic Characteristics. Hydrographs for the demonstration site are shown on Plate 5. Channel cross-sections are shown on Plate 6. The river channel in the vicinity of the demonstration site has been subject to commercial sand and gravel dredging at various times in the

past. Ice formation in the project area becomes significant only during unusually severe winters. Ice movement is not a factor in bank erosion at the site.

2. Hydraulic Characteristics. Velocity distribution measurements were made at the Moundsville demonstration site and were found to agree with the District computational method within 1/4 foot per second 81 percent of the time. From field observation the velocity distributions at the Powhatan Point site can be assumed to be almost identical to those at the Moundsville site. Average river velocities at the site for given discharges are as follows:

Discharge (cfs)	Frequency of Occurrence (years)	Average Velocity (fps)
20,000		0.7
100,000		3.2
220,000		5.5
283,000	10	5.9
348,000 (1972 flood)		6.1
398,000	100	6.8

Wave action was observed visually under various wind and traffic conditions. The maximum observed wave height was approximately one foot and was induced by traffic during low flow conditions. The minimum pool elevation is maintained at elevation 623 by the operation of Hannibal Locks and Dam 17 river miles downstream. Flows are controlled by eight gated bays, each 110 feet long, and 110-foot long fixed weir section. The dam gates are raised to pass high flows, so that the influence of the dam on the river decreases with increasing flow. At the demonstration site the influence of the dam during floods is insignificant. Prior to the completion of the Hannibal Project in 1975 the river at the demonstration site was maintained at minimum pool elevation 610.5 by Lock and Dam 14. The operation of the wicket type dams is described in paragraph II.A.3.

3. <u>Riverbank Description</u>. The riverbank at the demonstration site is roughly bisected by an inactive concrete ferry ramp and is characterized by a relatively shallow sloping bank upstream of the ramp and a high steep bank downstream. The bank is composed of fine grained alluvium deposited by past flood events in a thinly interbedded structure of fine sands, silts, and clays. In many areas the riverbank and beach is overlain by coal mine waste and other random fills in varied past attempts at encroachment or protection. The riverbank soils in two typical areas are delineated on Plate 7. The area immediately landward of the top of bank is relatively flat and serves chiefly as backyards. It ranges in width from a few feet to about 40 feet between the resident and commercial structures and the top of bank.

Erosion at the site is episodic with the majority of bank loss occurring during or immediately following periods of high water. The primary erosion mechanisms at this site are sloughing and piping followed by removal of the disturbed soil by river flows. Sloughing is the stability failure of a block of bank soil that results from saturation during high water and the related pore pressure and weight increase following the subsequent drawdown. Piping is the development of cavities in the bank face resulting from groundwater seepage concentrating in the more permeable sandy layers in the bank. The passage of water along these layers tends to remove individual particles of granular material at the face of the bank, in turn removing support for overlying materials.

The District has been aware of erosion at this site since the late sixties. Formal complaints from the Village of Powhatan Point began in May 1975, two months before the third and final increment of rise of the new Hannibal pool to elevation 623.0 and one month after the second increment of rise to elevation 617.8 Plate 7 and 8 shows the condition of the bank prior to the demonstration project.

III. DESIGN AND CONSTRUCTION

A. General.

The Powhatan Point site presented the opportunity to evaluate different schemes of bank protection along a reach of variable topography. Five of the six schemes used were designed to fit the variations in bank configuration with only a minimum of alteration to the original ground surface. Only in scheme five, where structural and vegetal features of protection were combined, was the riverbank altered to fit the design.

B. Basis for Design. The structural features included a rubber tire wall and blanket and a series of variations on the conventional stone bank protection design used by the District at that time. Steel furnace slag was used in lieu of stone because it is an economical, locally available material. The slag is a durable high density by-product of the basic oxygen or electric furnace steel making processes and should not be confused with lighter density blast furnace slag. The slag is graded into various sizes by the suppliers for sale as highway materials, railroad ballast, or fill material. The size range used for bank protection includes a varying percentage of refractory brick from ladle or furnace linings. The refractory material is a durable and angular component of the bank protection. Where a filter was placed between the slag protection and the underlying soil, a graded sand and gravel filter was used. The rubber tire wall was constructed with used automobile tires placed in staggered lifts and filled with gravel. The rubber tire blanket, also composed of used automobile tires was lashed together in a mat formation and laid over the surface of the beach extending from the toe of the tire wall to below normal pool elevation. This labor intensive scheme, using a common discarded material, was included in the project because it is feasible for use by small property owners with limited financial resources. The vegetal features, used only in scheme five included one shrub species and one variety of grass seed planted on a prepared cut slope above the tire wall. Originally

three varieties of shrubs were chosen on the basis of recommendations from other agencies, findings in the literature, and District experience, however at the time of construction only one was available.

C. Construction Details.

1. Scheme 1. This 356-foot reach of protection was constructed by placing a 6-inch minimum thickness of graded sand and gravel filter material beneath a one-foot thickness of graded steel furnace slag. The top of slag protection is at elevation 628.0 while the top of toe of the slag protection is at pool elevation (el. 623.0). The protection was placed on the original ground surface at approximately a one vertical to a minimum 1-1/2 horizontal slope. The filter material was graded between 3-inches and a number 100 sieve. The slag was graded between 2-inches and 12-inches. Details of scheme 1 are shown on Plate 9.

2. Scheme 2. Scheme 2 is 285 feet long and was constructed in the same manner as scheme 1 except that the toe of protection was trenched into the beach to elevation 621.0. Details of scheme 2 are shown on Plate 10.

3. Scheme 3. Scheme 3 is 500 feet long and consists of a 2-foot minimum thickness of slag protection on a slope of one vertical to a minimum of one horizontal. The protection was placed without a filter and without altering the original ground surface. The protection extends from elevation 630.0 to elevation 621.0. See Plate 11 for details.

4. Scheme 4. Scheme 4 is 240 feet long and was varied from scheme 3 by placing slag protection from elevation 627.0 to elevation 622.0 on a slope of one vertical to a minimum of two horizontal. Details of scheme 4 are shown on Plate 12.

5. Scheme 5. Scheme 5 was constructed along a 115-foot reach with combined structural and vegetal features. The structural features included a combined automobile tire wall and blanket. The wall consisted of tires stacked in a staggered arrangement with each tier set back one foot from the tier below and every other tier anchored with 3-foot long U-shaped steel reinforcement bars. The wall extended from elevation 623.5 to elevation 628.0. Sand and gravel was used as a tire fill and as a backfill. The tire blanket, extending to the pool from the toe of the tire wall, consisted of a tire mat structure one tire thick and 6 tires wide. The blanket, with a plastic woven filter cloth beneath, was placed on the beach surface and lashed together by nylon rope and anchored with 3-foot long U-shaped steel reinforcement bars. The tires and interstices between were filled with sand and gravel. Above the tire wall, the riverbank was excavated to a one vertical on two horizontal slope, and seeded and planted with a Silky Dogwood shrub on a 2-foot grid spacing. The shrubs were planted through a biodegradable erosion control fabric and extended from the top of the tire wall at elevation 628.0 to the top of the bank at approximate elevation 636.0. Details of scheme 5 are shown on Plate 13.

6. Scheme 6. Scheme 6 is 500 feet long and consists of a dike-like structure of steel furnace slag placed along the beach at a distance of at least 12 feet riverward from the face of the bank. The structure is 3 feet to 5 feet high with a riverward slope of one vertical on one and a half horizontal and a landward slope of one vertical on one horizontal. The top of the structure, fixed at elevation 625.0, has a minimum width of one foot. Details of Scheme 6 are shown on Plate 14.

D. Costs. The contractor received notice to proceed on 15 October 1978 and completed the work on 6 February 1979. The final contract cost was $121,529 which included four modifications totaling $5,092. The unit prices included $22 per cubic yard for 380 cubic yards of unclassified excavation, $37 per cubic yard for 1,810 cubic yards of

slag protection, $30 per cubic yard for 255 cubic yards of graded filter material, $8 per square foot for 540 square feet of rubber tire wall, $8.90 per square foot for 1,550 square feet of rubber tire blanket, $7 apiece for 944 plants, and $2 per square yard for 230 yards of seeding. The final construction cost per linear foot and per square foot for each scheme was as follows:

SCHEME	COST PER LINEAR FOOT	COST PER SQUARE FOOT
1	$ 51	$ 2.11
2	$ 50	$ 2.95
3	$ 59	$ 2.95
4	$ 39	$ 3.03
5 (Structural)	$208	$17.36
5 (Vegetal)	$ 57	$ 7.18
6	$ 15	$ 2.91

The supervision and inspection cost was $10,300 and the engineering and design cost was $44,800.

IV. PERFORMANCE OF PROTECTION

A. Monitoring Program. The Pittsburgh District Section 32 monitoring program is summarized on Plate 15. Instrumentation at the site was limited to a staff gage that is read twice daily by a paid observer. Air temperature and precipitation are measured at the Hannibal and Pike Island navigation projects. Monitoring inspections by project designers have been made on the average once every two months. These inspections include visual observations and photographs taken from fixed reference points. Overbank cross-sections were surveyed before construction, in July 1976, in July 1977 and just before the end of construction in November 1978. The site will be resectioned in April 1982. Soil samples were taken at the site in March 1977 and were tested for grada-

tion, water content, Atterberg limits, and agronomic properties. Quantitative leachate analyses of slag were made on samples taken at potential supply sources in January 1975 and July 1976, and on samples taken from inplace bank protection in February 1980. Further testing of in-place slag is scheduled for 1981, 1982, and 1983. Controlled vertical low level aerial photography was taken in the spring of 1977, fall of 1978, and the spring and fall of 1980. Low angle oblique aerial photography was taken in the fall of 1978. Plates 16 and 17 show vertical aerial photographs of the site taken in September 1978 and March 1980.

B. Evaluation of Protection Performance.

1. General. Overall project performance has been effective since construction. All six schemes have substantially reduced the severity of erosion from that which occurred before the project. Erosion that has occurred along the project reach has been limited to the bank above the protection. During the completion phase of construction, the project experienced, in a two month period, three high waters that exceeded the one-year frequency flood. The upper bank erosion that resulted from this unusual occurrence has been the most significant loss to date.

2. Scheme 1 and Scheme 2. The slag of both schemes has shown no signs of displacement or deterioration. The toe protection of both remains intact and no advantage to either design can yet be determined. The upper bank exhibits a small advance of the high water erosion scarp that existed prior to slag protection placement. Sequential photos of Scheme 1 are shown on Plates 18 and 19 and of Scheme 2 on Plates 20 and 21.

3. Scheme 3 and Scheme 4. The slag protection of these two schemes have performed effectively. The lack of filter has not been detrimental to the performance of the relatively thick layer of protection. The upper bank of Scheme 3, which is composed mostly of coal refuse fill, has been subjected to continued erosion from overbank

drainage and sloughing of portions oversteepened by preproject lower bank erosion. The Scheme 4 upper bank, which extends from elevation 627, has suffered from all three high waters of early 1979. Although a local gas line was exposed in the process, the extent of erosion has been minor. Photos of Schemes 3 and 4 can be seen on Plates 22, 23, 24, and 25.

4. Scheme 5. Of all the schemes, only the reach of Scheme 5 offered the opportunity to change the bank configuration to fit the scheme design. Alterations to the upper bank within the reach of the first four schemes was prevented by features landward form the top of bank, while the reach of Scheme 6 lacked easements above ordinary high water (627.1 NGVD).

The Scheme 5 rubber tire wall and blanket, with a laid back and vegetated upper bank, has remained intact and stable since construction, providing effective protection from erosion. Vandalism to the structure has not occurred because it has been well anchored and public access is difficult. Although the Kentucky 31 mixture of grasses has overgrown the silky dogwood (cornus amomum) on the upper bank, the shrub shows definite signs of succeeding as a cover plant. However, since the upper bank was not seeded and planted until May 1979, the vegetation to date has not been subjected to possibly damaging high water episodes. Performance of the vegetal features of the project is summarized on Plate 26. Plates 27, 28 and 29 show photos of Scheme 5.

5. Scheme 6. The longitudinal slag dike of Scheme 6, designed as a sediment trap, has been functioning as intended. Placing the dike riverward of the water's edge with its top above pool level, has resulted in trapping sediment from high waters and soil sloughs from the bank face. Within a year of placement, soil has accreted within the enclosure to the top of dike. The enclosure has now become well vegetated and apparently continues to accrete. Although some recession of

the upper bank is occurring, the rate of recession has been drastically reduced as a result of this lower terrace development. Plates 30, 31 and 32 show photos of Scheme 6.

C. Rehabilitation. No rehabilitation has been performed. Minor additional rehabilitation work may be required depending upon future performance.

D. Summary of Findings. Graded steel furnace slag, when placed in a 12-inch thickness atop filter material or in a 24-inch thickness without a filter, has been shown to be effective in controlling erosion. Used automobile tires that are combined to form either a wall or mat have been shown to be an effective means of erosion control well suited to use by an individual property owner with limited financial means. The sediment trap of Scheme 6 appears to have been effective in retarding bank erosion, but further monitoring is needed to confirm its effectiveness.

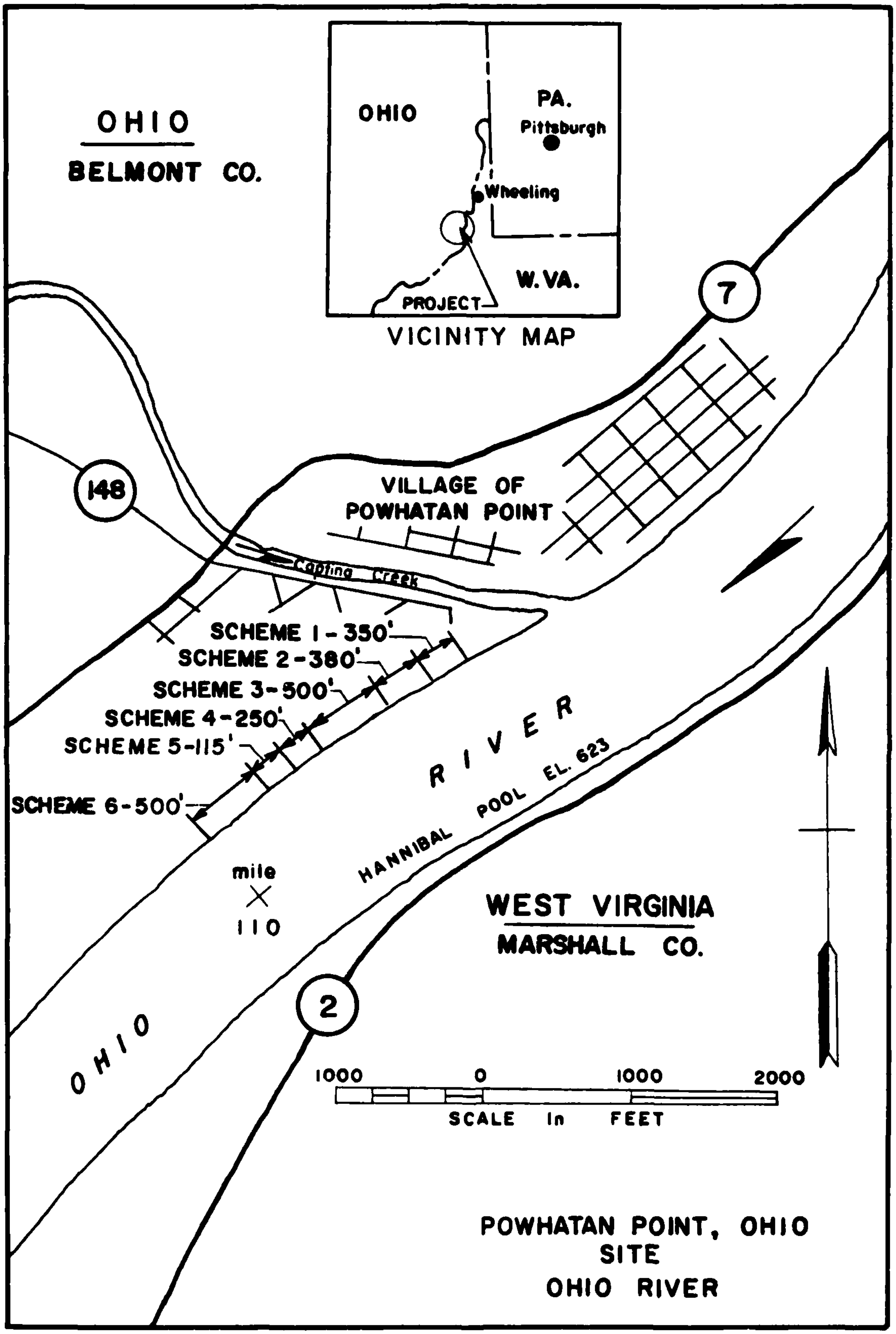
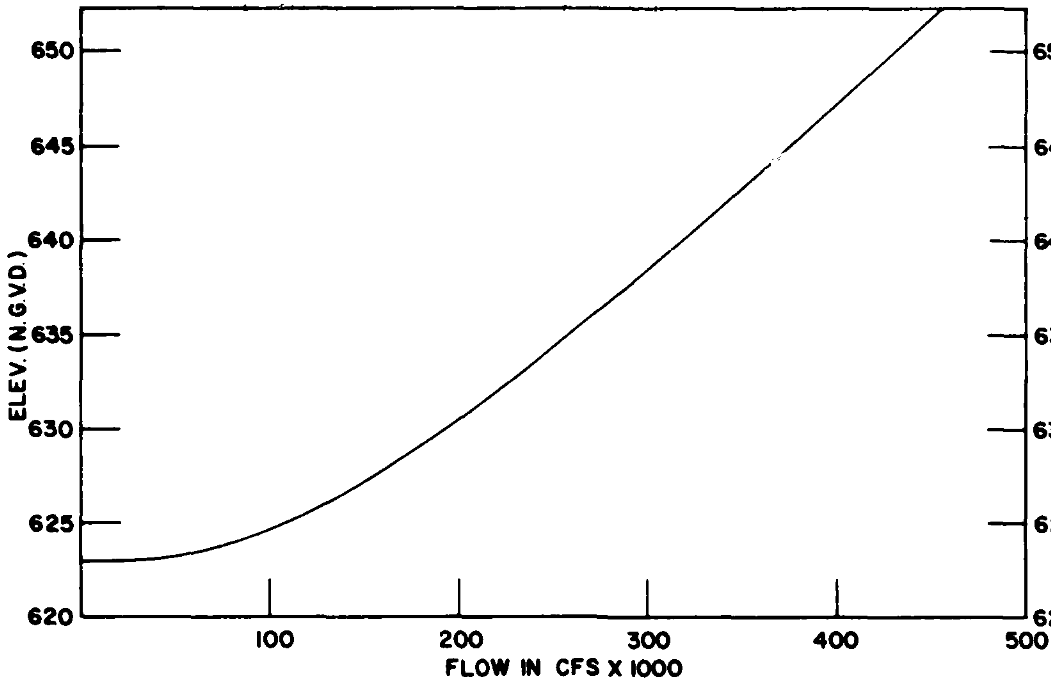
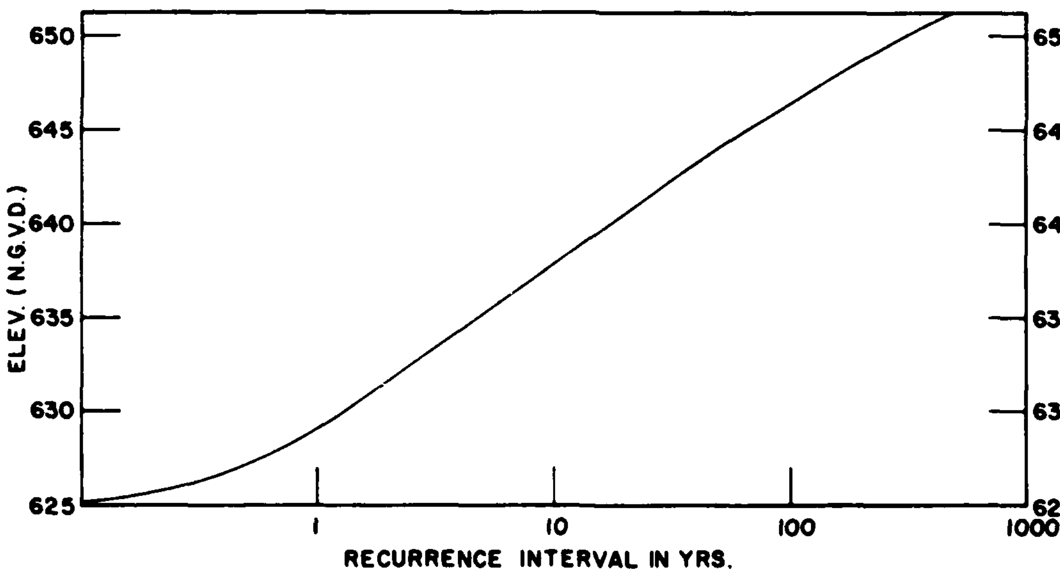

OHIO
BELMONT CO.
OHIO
PA.
Pittsburgh
Wheeling
W. VA.
PROJECT
VICINITY MAP
7
148
VILLAGE OF
POWHATAN POINT
Captina Creek
SCHEME 1 - 350'
SCHEME 2 - 380'
SCHEME 3 - 500'
SCHEME 4 - 250'
SCHEME 5 - 115'
SCHEME 6 - 500'
RIVER
HANNIBAL POOL EL. 623
mile
110
WEST VIRGINIA
MARSHALL CO.
2
OHIO
1000
0
1000
2000
SCALE In FEET
POWHATAN POINT, OHIO
SITE
OHIO RIVER

PLATE 1



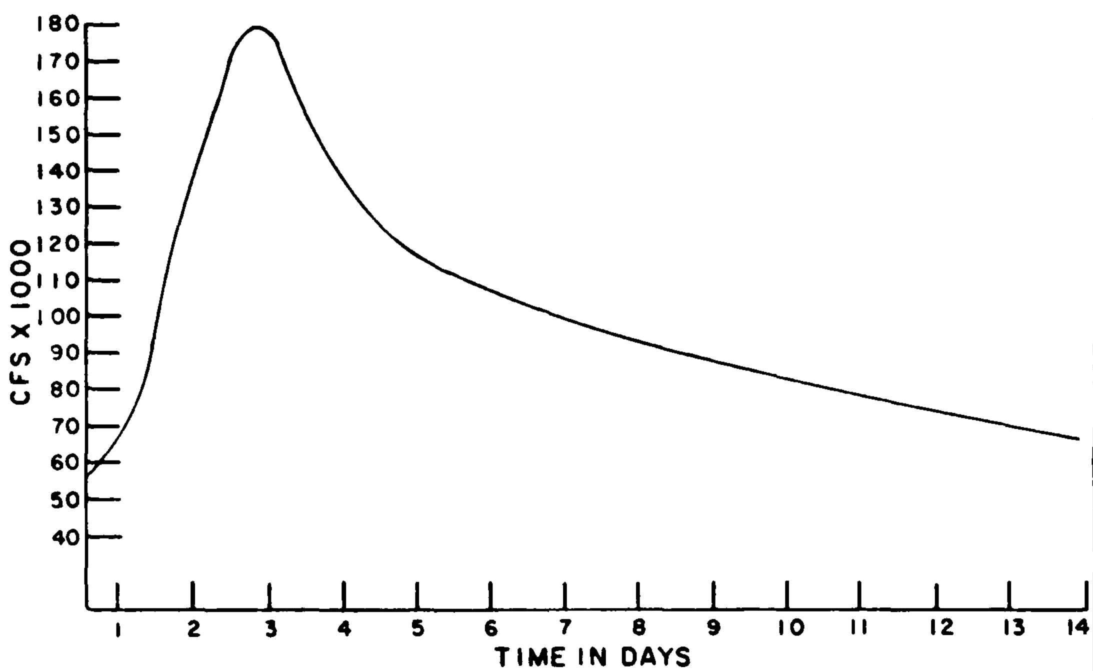
DISCHARGE RATING CURVE MI. 109.7



STAGE FREQUENCY CURVE MI. 109.7

POWHATAN POINT, OHIO
SITE
OHIO RIVER

PLATE 2



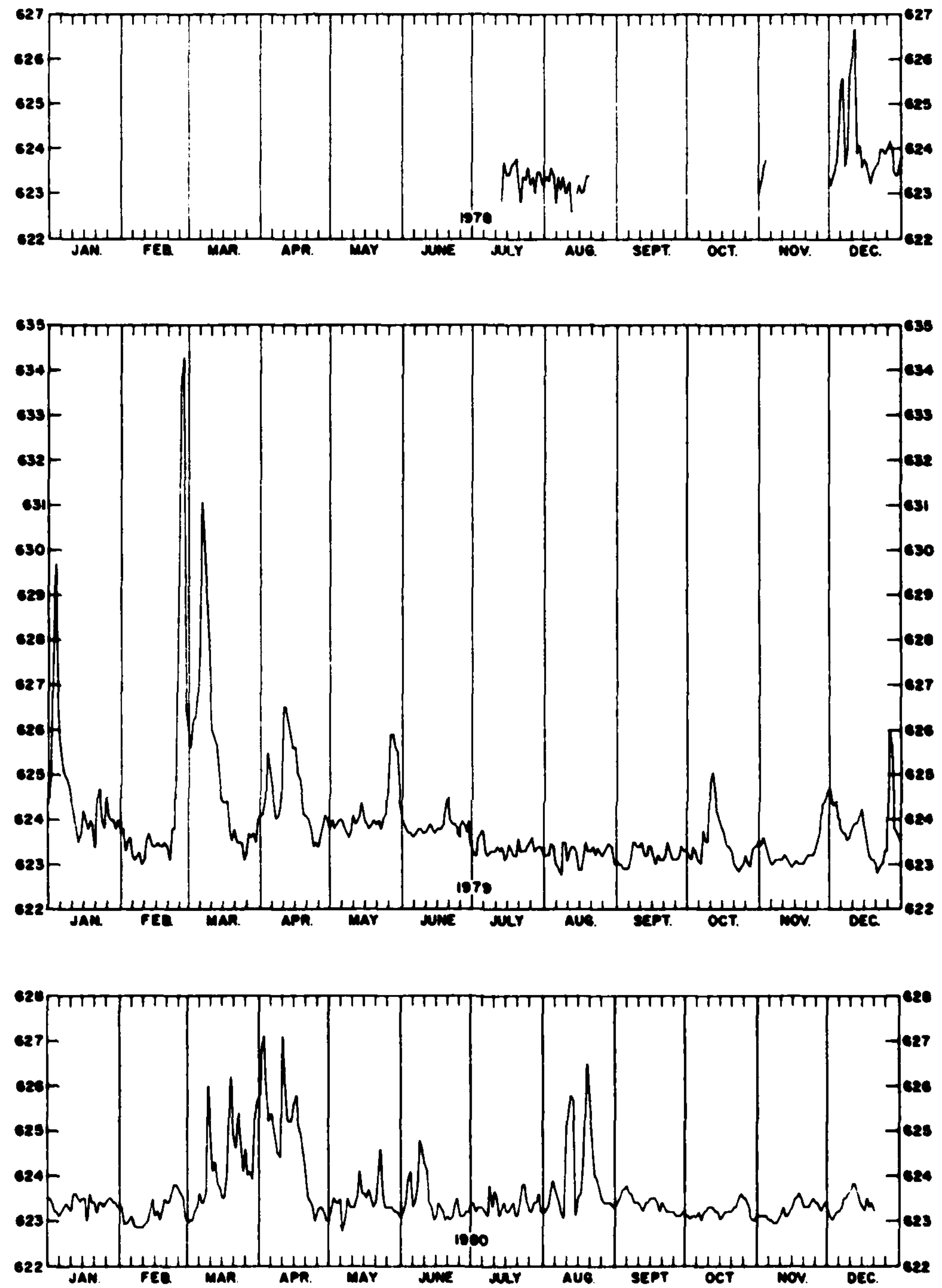
ONE YEAR FLOOD HYDROGRAPH
POWHATAN POINT, OHIO
SITE
OHIO RIVER

PLATE 3

PARAMETER mg/l	SLAG IN RIVER WATER	SLAG IN D.I. WATER	RIVER WATER	W. VA. CRITERIA 1980	EPA CRITERIA 1972
Alkalinity M.O.	64	36	43		
Arsenic (As)	< 0.005	< 0.005	< 0.005	0.05	0.01
Barium (Ba)	< 0.1	< 0.1	< 0.1	1.0	1.0
Cadmium (Cd)	< 0.01	< 0.01	< 0.01	0.01	0.01
Chloride (Cl)	27	2	26	250	250
Chromium (Cr^{+6})	0.003	0.003	< 0.002	0.05	0.05
Chromium Total	< 0.02	< 0.03	< 0.03		
Color (APHA)	0-5	0-5	20-30		75
Copper (Cu)	< 0.02	< 0.02	< 0.02	0.005	1.0
Cyanide Total (Cn)	0.005	0.001	0.016	0.025	0.2
Fluoride (F)	0.56	0.18	0.21	1.0	
Hardness ($CaCO_3$)	153	53	125		
Iron Total (Fe)	0.15	0.04	1.0	1.0	0.3
Lead (Pb)	< 0.05	< 0.05	< 0.05	0.05	0.05
Magnesium (Mg)	9.0	0.54	9.5		
Manganese (Mn)	0.04	< 0.02	0.33	0.05	0.05
Mercury (Hg) ug/l	< 0.2	< 0.2	< 0.2	0.2	2.0
Nitrate (N)	1.0	< 0.2	1.2	10.0	10.0
PH	7.1	8.0	7.6	6.0-9.0	5.0-9.0
Phenol	0.003	0.004	0.004	0.005	0.001
Selenium (Se)	< 0.005	< 0.005	< 0.005	0.005	0.01
Silver (Ag)	< 0.02	< 0.02	< 0.02	0.05	
Solids Dissolved	311	33	224		
Solids Suspended	< 1	< 1	18		
Solids Total	327	63	246		
Sulfate (SO_4)	110	< 2.5	98		250
Sulfide (S)	< 0.02	< 0.02	< 0.02		
Zinc (Zn)	< 0.02	< 0.02	< 0.02	0.05	5.0

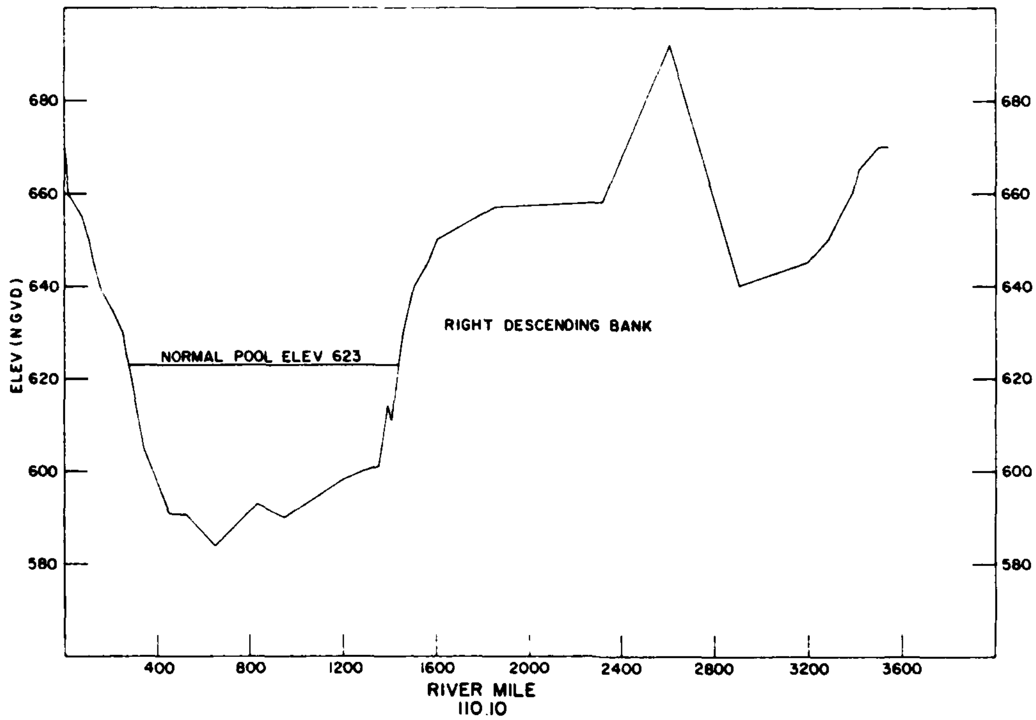
SLAG LEACHATE COMPARISON
POWHATAN POINT, OHIO
SITE
OHIO RIVER

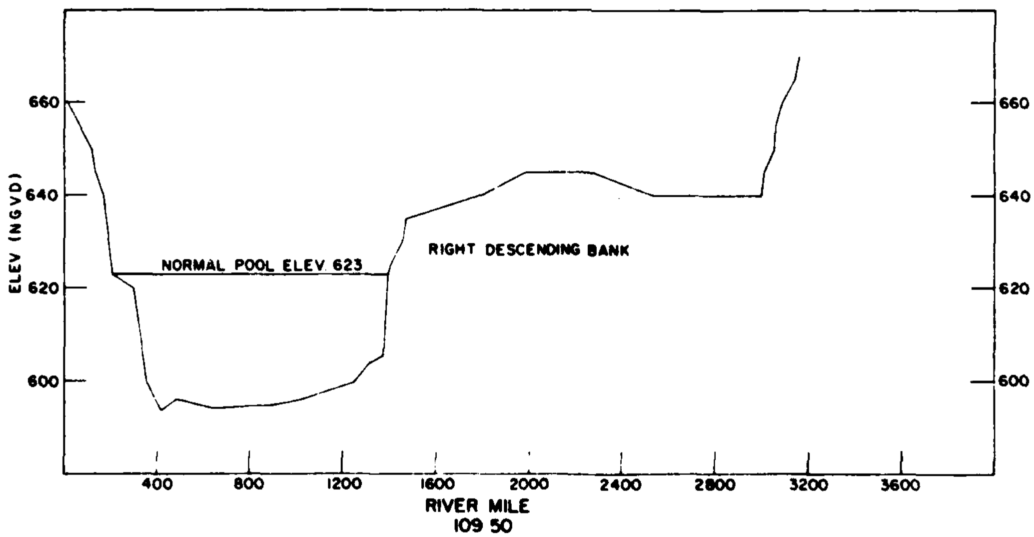
PLATE 4



HYDROGRAPHS
POWHATAN POINT, OHIO
SITE
OHIO RIVER

PLATE 5





CHANNEL CROSS SECTIONS
POWHATAN POINT, OHIO
SITE
OHIO RIVER

PLATE 6

FILL (mainly coal refuse)

THINLY INTERBEDDED FINE SANDY SILTS & CLAYEY SILTS WITH PI = 10 and LL = 37

VICINITY OF STATION 10+75
1 AUGUST 1978

FILL (SANDY CLAYEY SILT with fragments of reddog and coal)

THINLY INTERBEDDED FINE SANDY SILTS & CLAYEY SILTS WITH PI = 15 & LL = 47

VICINITY OF STATION 13+00
1 AUGUST 1978

RIVERBANK SOILS
POWHATAN POINT, OHIO
SITE
OHIO RIVER

PLATE 7

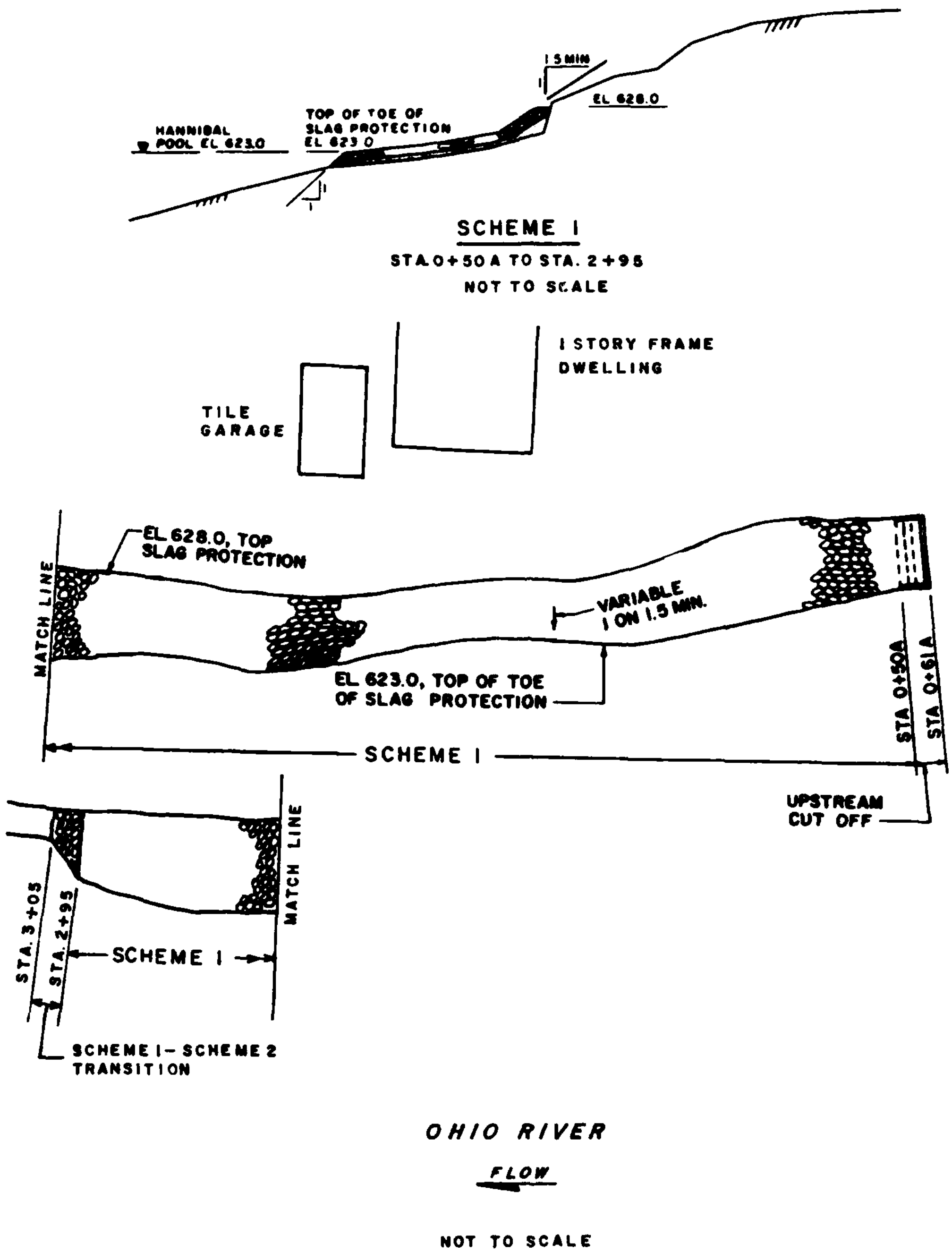
BETWEEN APPROXIMATE STATIONS 9+00 AND 10+50
MARCH 1958

VICINITY OF STATION 15+00
5 MAY 1977

VICINITY OF STATION 4+50
8 MARCH 1977

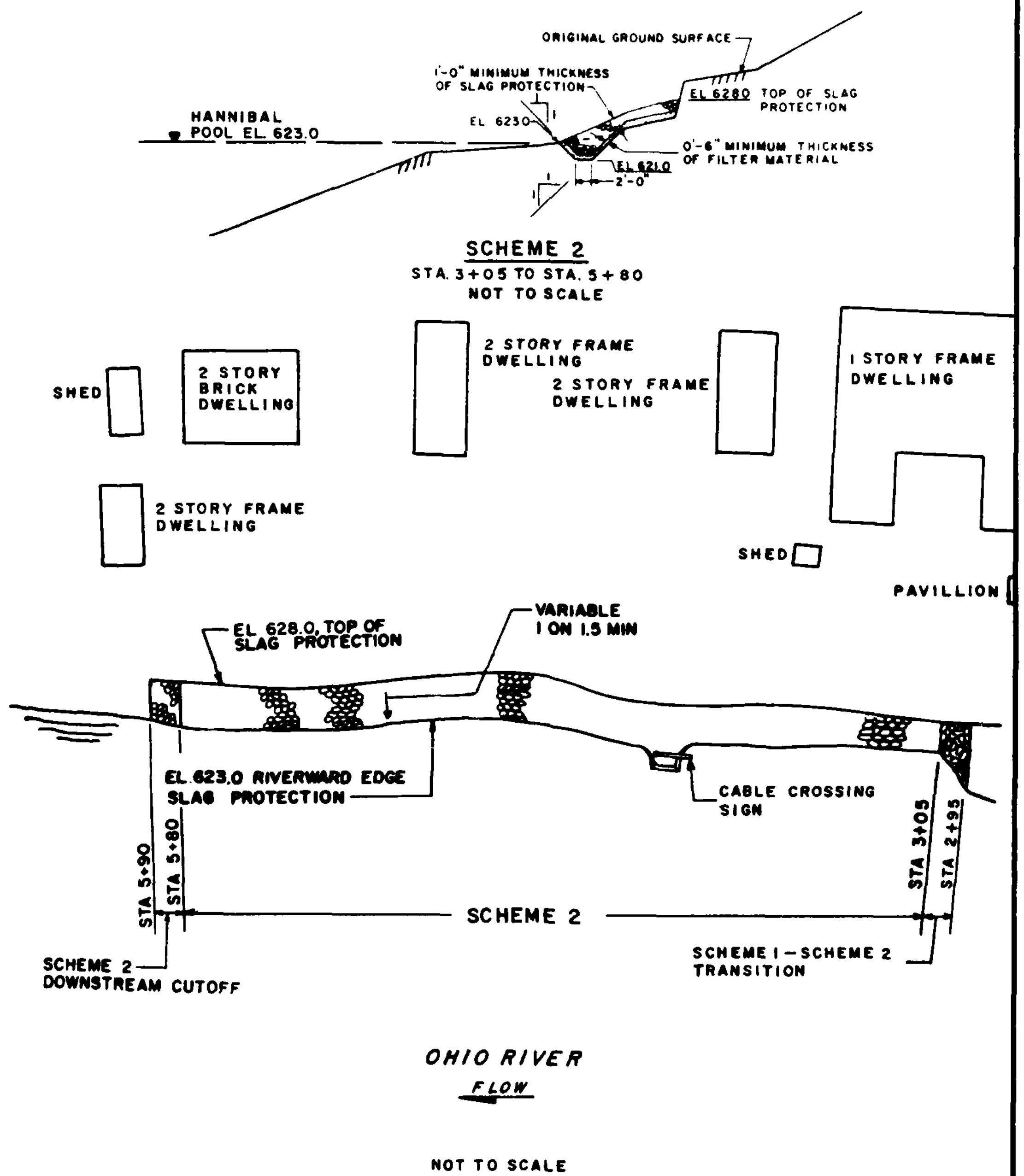
SITE PHOTOS
POWHATAN POINT, OHIO
SITE
OHIO RIVER

PLATE 8



SCHEME I
POWHATAN POINT, OHIO
SITE
OHIO RIVER

PLATE 9



SCHEME 2
POWHATAN POINT, OHIO
SITE
OHIO RIVER

PLATE 10

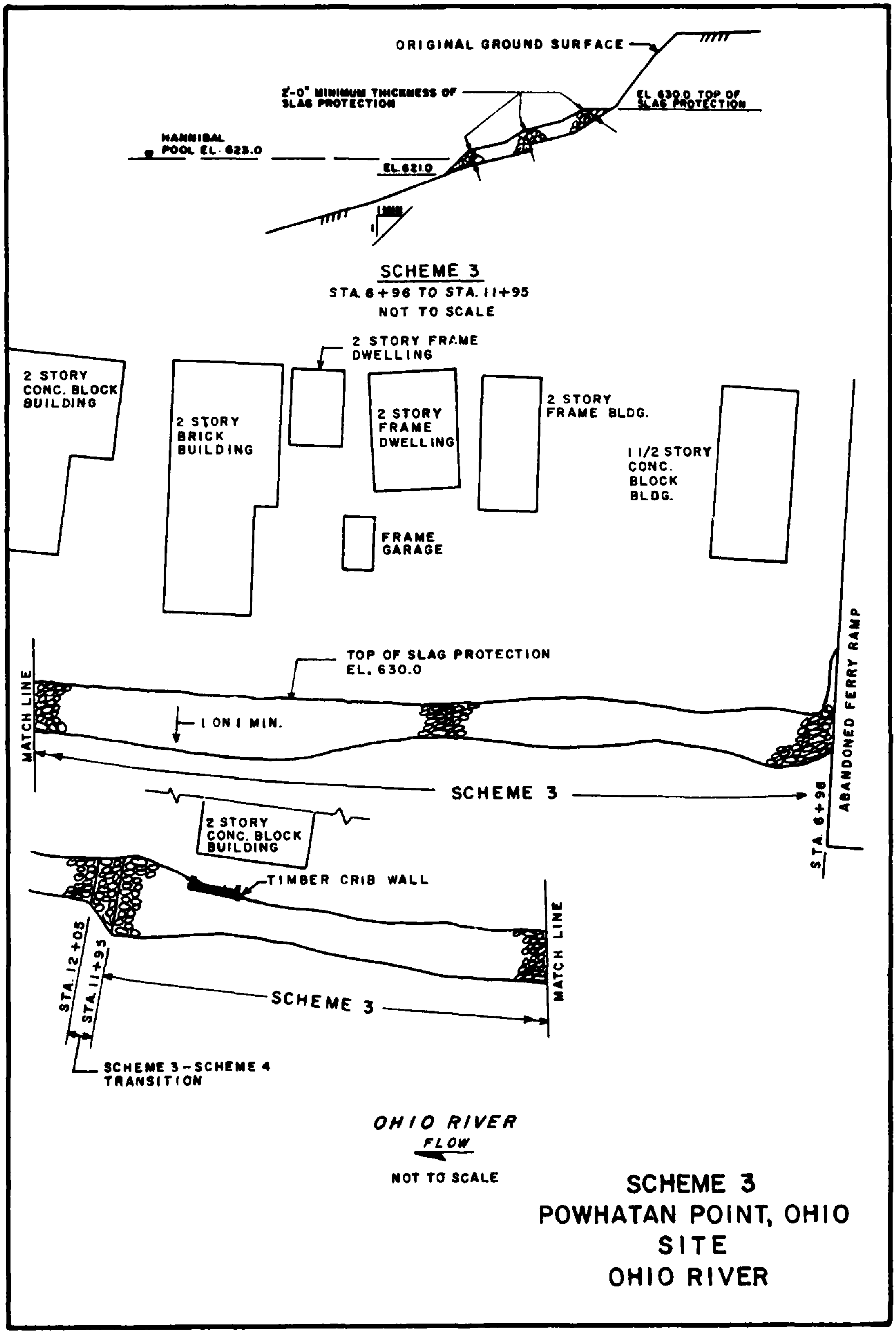
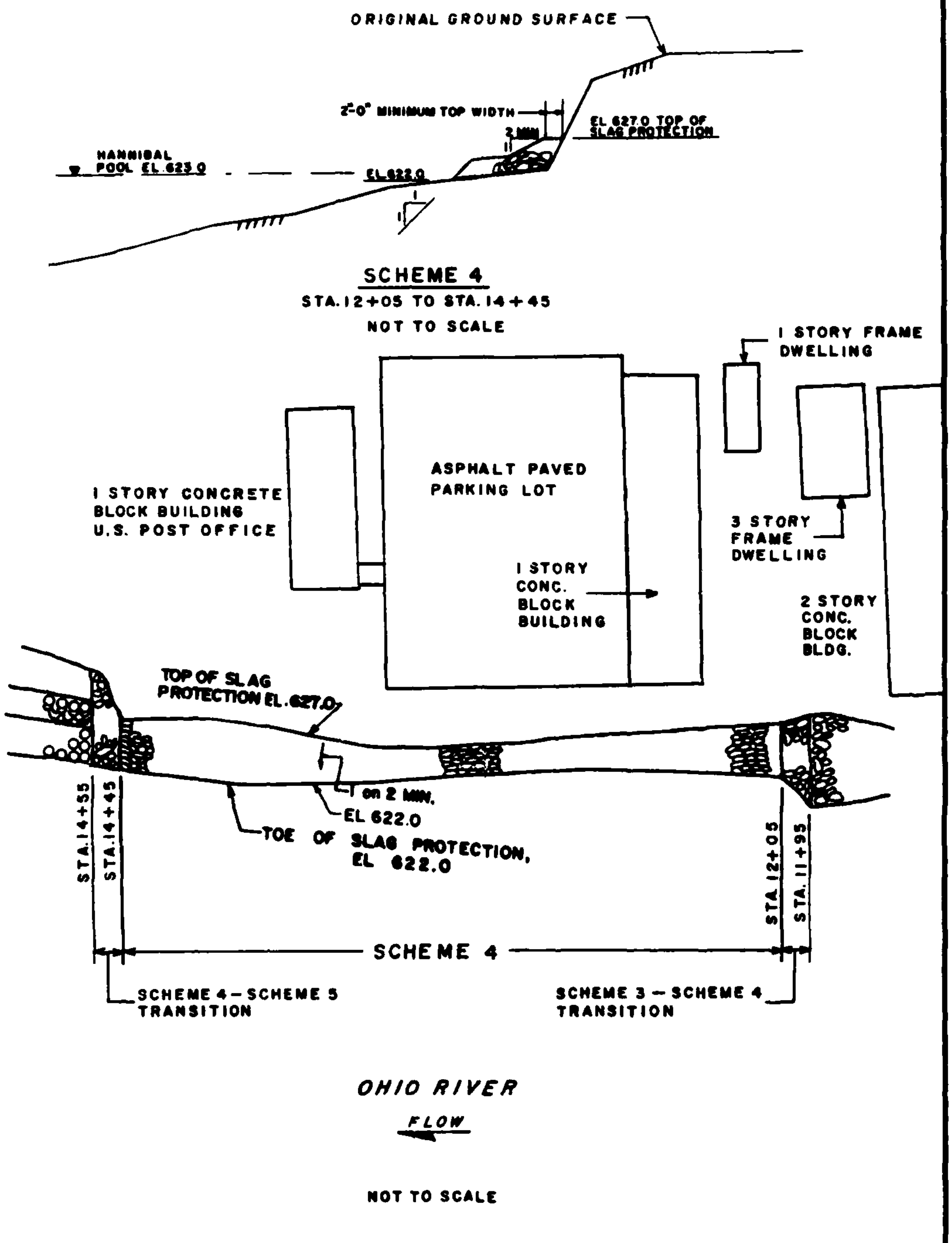
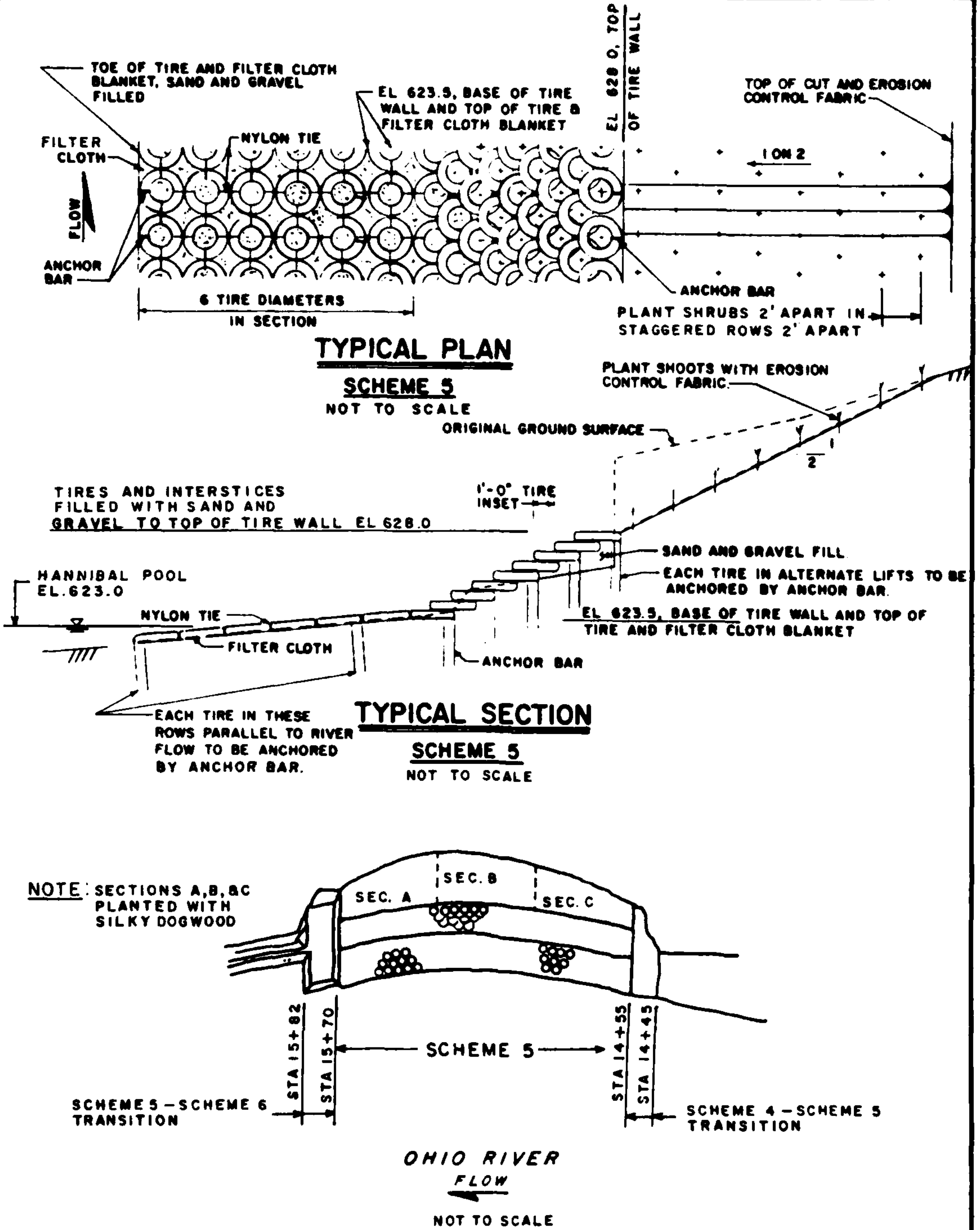

ORIGINAL GROUND SURFACE
2'-0" MINIMUM THICKNESS OF SLAG PROTECTION
EL 630.0 TOP OF SLAG PROTECTION
HANNIBAL POOL EL. 623.0
EL 621.0
SCHEME 3
STA. 6+96 TO STA. 11+95
NOT TO SCALE
2 STORY FRAME DWELLING
2 STORY CONC. BLOCK BUILDING
2 STORY BRICK BUILDING
2 STORY FRAME DWELLING
2 STORY FRAME BLDG.
1 1/2 STORY CONC. BLOCK BLDG.
FRAME GARAGE
TOP OF SLAG PROTECTION EL. 630.0
1 ON 1 MIN.
MATCH LINE
SCHEME 3
ABANDONED FERRY RAMP
STA. 6+96
2 STORY CONC. BLOCK BUILDING
TIMBER CRIB WALL
STA. 12+05
STA. 11+95
SCHEME 3
MATCH LINE
SCHEME 3 - SCHEME 4 TRANSITION
OHIO RIVER
FLOW
NOT TO SCALE
SCHEME 3
POWHATAN POINT, OHIO
SITE
OHIO RIVER

PLATE 11



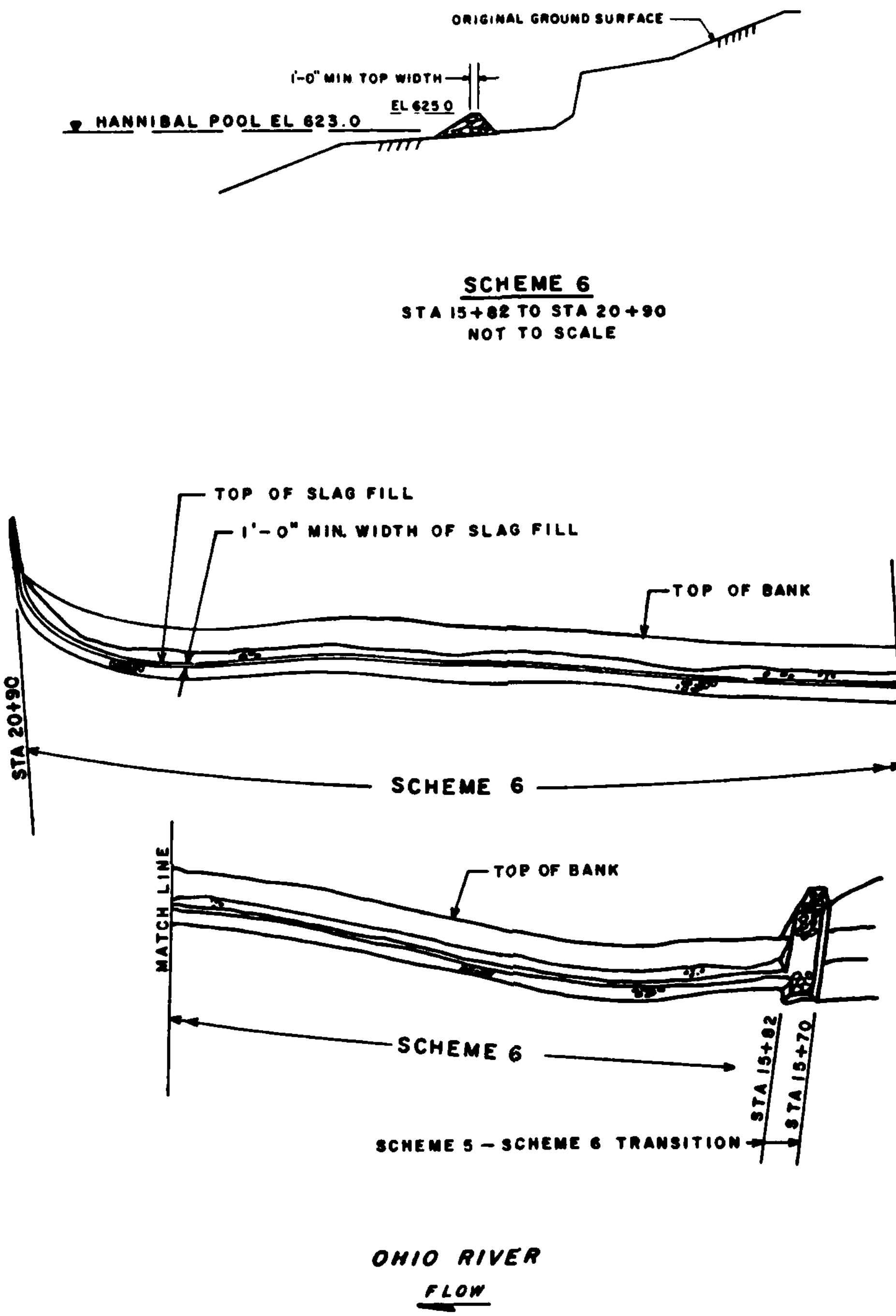
SCHEME 4
POWHATAN POINT, OHIO
SITE
OHIO RIVER

PLATE 12



SCHEME 5
POWHATAN POINT, OHIO
SITE
OHIO RIVER

PLATE 13



SCHEME 6
POWHATAN POINT, OHIO
SITE
OHIO RIVER

PLATE 14

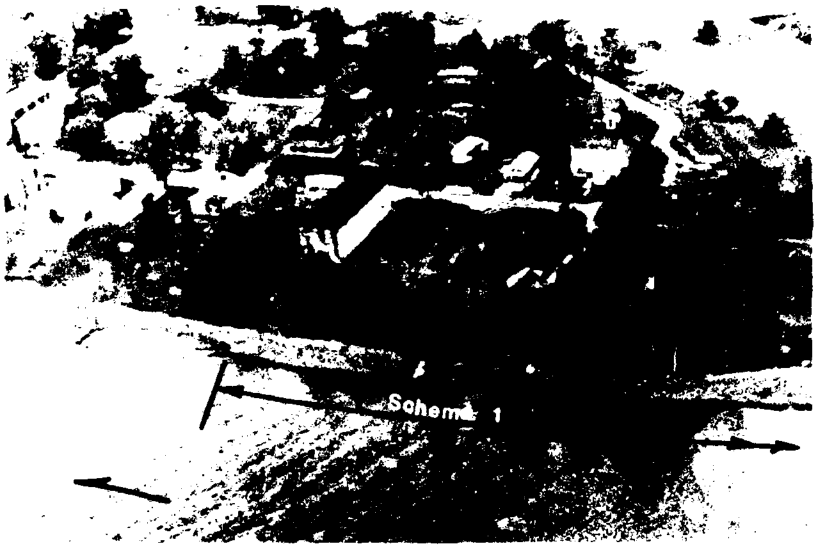
PARAMETER	ITEM	FREQUENCY
GEOMETRY	1. Overbank crossections form baseline to 50 ft. riverward of water's edge at 50 ft. intervals	Biyearly
	2. Full channel crossections	Once
	3. Ground photos from fixed reference points	Monthly
	4. Controlled vertical low level aerial photos	Annual
CLIMATE	1. Air temp., precip., wind direction and velocity (recorded at Moundsville, WV Site)	Continuous
	2. Ice conditions, snow cover noted from visual observations	As available
HYDRAULICS	1. River stage record from staff gage near sta. 10+00	Twice daily by observer
	2. River traffic (through observation and lock records)	As available
STREAM-BANK PROTECTION	1. Monitor dimensional changes of marked structural & vegetal units through photos and manual measurement	Monthly
	2. Observe durability of marked units of structural material (qualitative)	Monthly
	3. Observe condition of marked plants	Monthly
	4. Record initiation and measure progression of failures in bank protection	Monthly
GEOLOGY AND SOILS	1. Material properties testing	Annual

MONITORING PROGRAM
POWHATAN POINT, OHIO SITE
OHIO RIVER

PLATE 15

PLATE 16

PLATE 17



AERIAL VIEW
15 MAY 1979

FROM STATION 1+00
25 OCTOBER 1979

SCHEME 1 PHOTOS
POWHATAN POINT, OHIO
SITE
OHIO RIVER

PLATE 18

FROM STATION 1+00
6 FEBRUARY 1980

FROM STATION 1+00
8 APRIL 1980

FROM STATION 1+00
3 DECEMBER 1980

SCHEME 1 PHOTOS
POWHATAN POINT, OHIO
SITE
OHIO RIVER

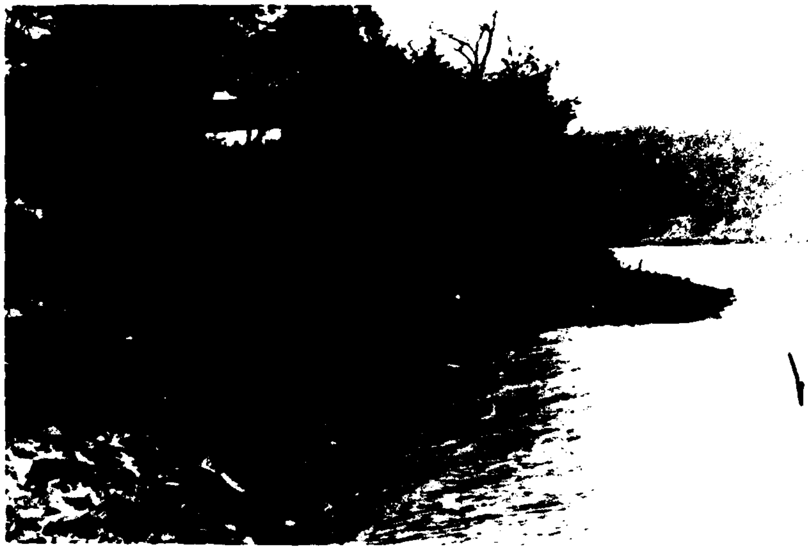
PLATE 19

FROM STATION 4+00
15 MARCH 1979

AERIAL VIEW
15 MAY 1979

SCHEME 2 PHOTOS
POWHATAN POINT, OHIO
SITE
OHIO RIVER

PLATE 20

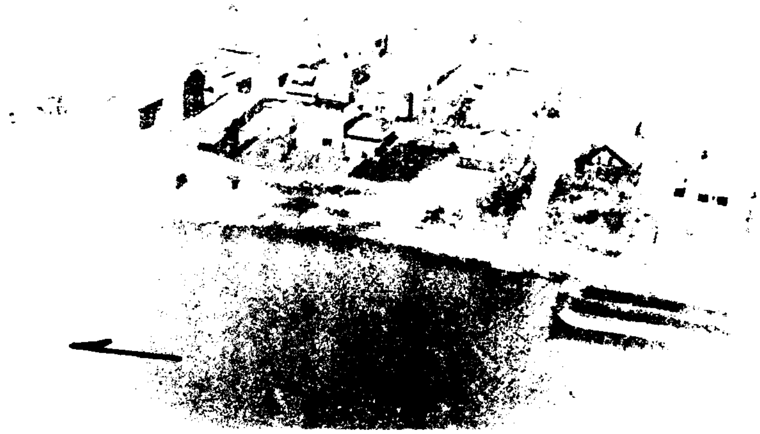


FROM STATION 4+00
25 OCTOBER 1979

FROM STATION 4+00
8 APRIL 1980

SCHEME 2 PHOTOS
POWHATAN POINT, OHIO
SITE
OHIO RIVER

PLATE 21



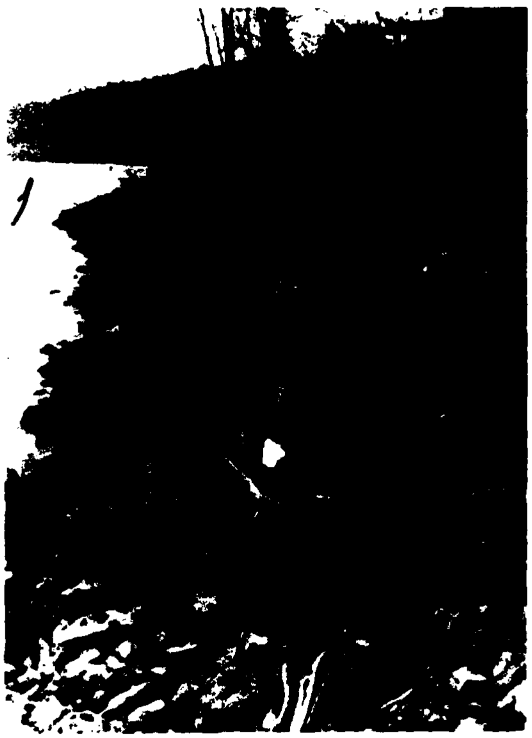
AERIAL VIEW BEFORE CONSTRUCTION
17 APRIL 1974

FROM STATION 7+20
15 MARCH 1979

SCHEME 3 PHOTOS
POWHATAN POINT, OHIO
SITE
OHIO RIVER

PLATE 22

AERIAL VIEW
15 MAY 1979



FROM STATION 7+20
25 OCTOBER 1979

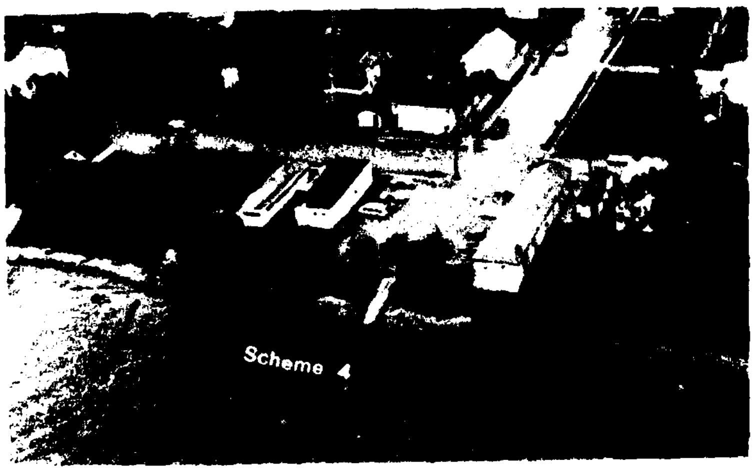
FROM STATION 7+20
8 APRIL 1980

SCHEME 3 PHOTOS
POWHATAN POINT, OHIO
SITE
OHIO RIVER

PLATE 23

BEFORE CONSTRUCTION
AERIAL VIEW
17 APRIL 1974

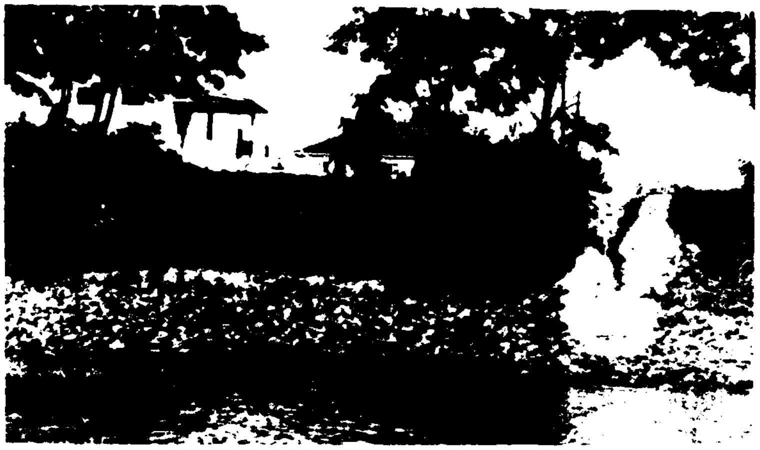
FROM STATION
14+30
15 MARCH 1979



AERIAL VIEW
15 MAY 1979

SCHEME 4 PHOTOS
POWHATAN POINT, OHIO
SITE
OHIO RIVER

PLATE 24



VICINITY OF
STATION 13+00
28 JUNE 1979

FROM STATION
14+30
6 FEBRUARY 1980

FROM STATION 14+30
3 DECEMBER 1980

SCHEME 4 PHOTOS
POWHATAN POINT, OHIO
SITE
OHIO RIVER

PLATE 25

SCHEME (1)	SECTION (2)	INITIAL SPACING (3)	% OF PLANTED SECTION GROWING (4)	(PER SQ FT) DENSITY INCREASE OR DECREASE (5)	CONDITION OF PLANTS (6)	COMPARATIVE VALUE (7)	DATE PLANTED MAY 1979 / CURRENT DATE MAY 1980 (8) — REMARKS (9)
5	A	2' x 2' O.C.	90	SAME	FAIR	190	Grass is taller than plants.
	B	2' X 2' O.C.	90	SAME	FAIR	190	Same
	C	2' X 2' O.C.	90	SAME	FAIR	190	Same

COMPARATIVE VALUE RATIONALE. IN ORDER TO GIVE EACH PLANTED SECTION A VALUE TO INDICATE THE DEGREE OF PLANT SUCCESS, THE VALUES LISTED IN COLUMNS 4,5 & 6 ARE COMBINED TO FORM A TOTAL COMPARATIVE VALUE AS SHOWN IN COLUMN 7. A COMPARATIVE VALUE OF 300 IS MAXIMUM. A VALUE OF 0 IS MINIMUM, INDICATING PLANT FAILURE IN ALL CATEGORIES.

THE VALUE OF COLUMN 4 IS EQUAL TO THE PERCENT SHOWN, AND REPRESENTS THE PERCENT OF THE SECTION COVERED BY PLANTS.

COLUMN 5 VALUES:
- EXCEPTIONAL INCREASE OR VERY GOOD GERMINATION — 100
- INCREASE OR GOOD GERMINATION — 75
- SAME OR POOR GERMINATION — 50
- DECREASE OR VERY POOR GERMINATION — 25
- BLANK SPACE OR 0 — 0

COLUMN 6 VALUES:
- EX (EXCELLENT) — 100
- GOOD — 75
- FAIR — 50
- POOR — 25
- BLANK SPACE OR 0 — 0

PLANT MATERIAL EVALUATION
POWHATAN POINT, OHIO
SITE
OHIO RIVER

PLATE 26

BEFORE CONSTRUCTION LOOKING
UPSTREAM FROM STATION 16+10
12 MAY 1978

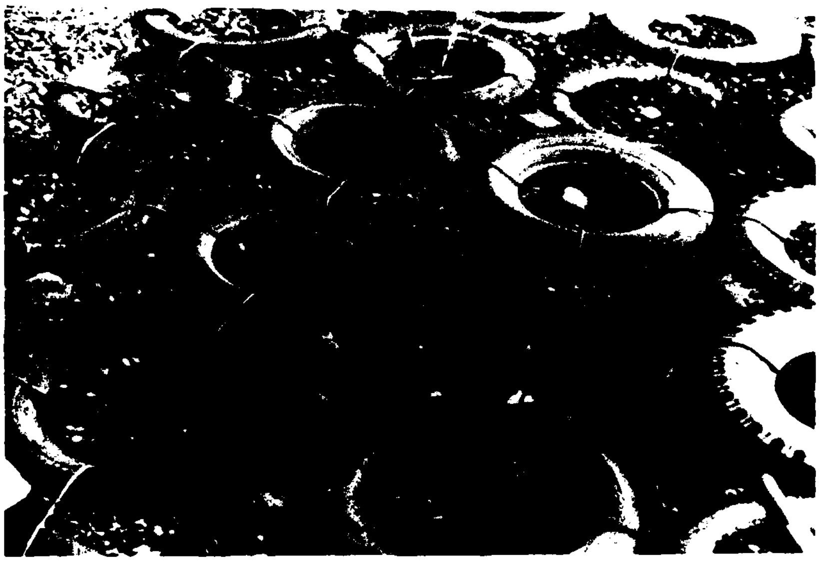
DURING CONSTRUCTION
FROM STATION 14+50
2 MARCH 1979

AERIAL VIEW
15 MAY 1979

SCHEME 5 PHOTOS
POWHATAN POINT, OHIO
SITE
OHIO RIVER

PLATE 27

FROM STATION 14+50
7 JUNE 1979



VIEW OF TIRE BLANKET
7 JUNE 1979

SCHEME 5 PHOTOS
POWHATAN POINT, OHIO
SITE
OHIO RIVER

PLATE 28

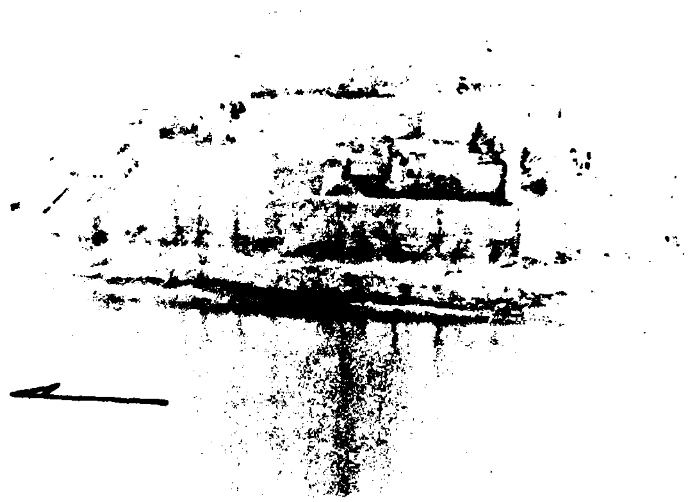
LOOKING DOWNSTREAM
FROM STATION 14+50
25 OCTOBER 1979

LOOKING DOWNSTREAM
FROM STATION 14+50
8 APRIL 1980

LOOKING DOWNSTREAM
FROM STATION 14+50
3 DECEMBER 1980

SCHEME 5 PHOTOS
POWHATAN POINT,OHIO
SITE
OHIO RIVER

PLATE 29



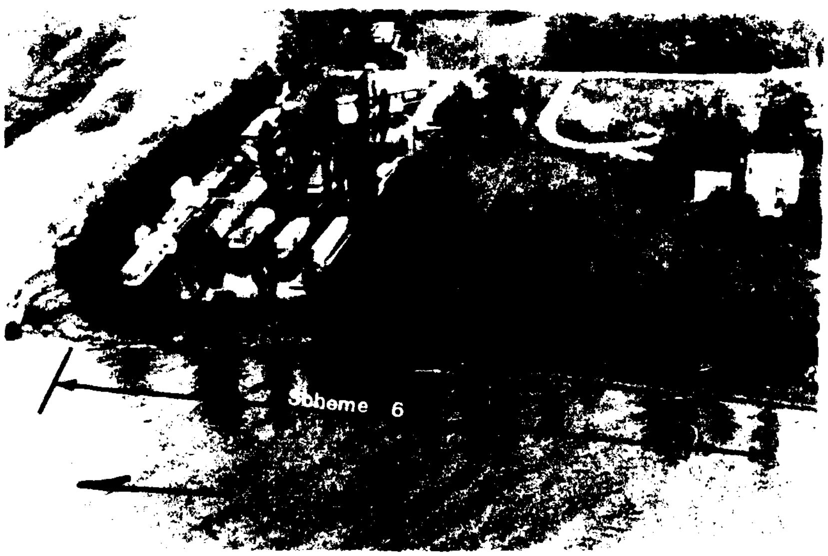
BEFORE CONSTRUCTION
AERIAL VIEW
17 APRIL 1974

FROM STATION 15+75
15 MARCH 1979

SCHEME 6 PHOTOS
POWHATAN POINT, OHIO
SITE
OHIO RIVER

PLATE 30

FROM STATION 17+00
29 MARCH 1979

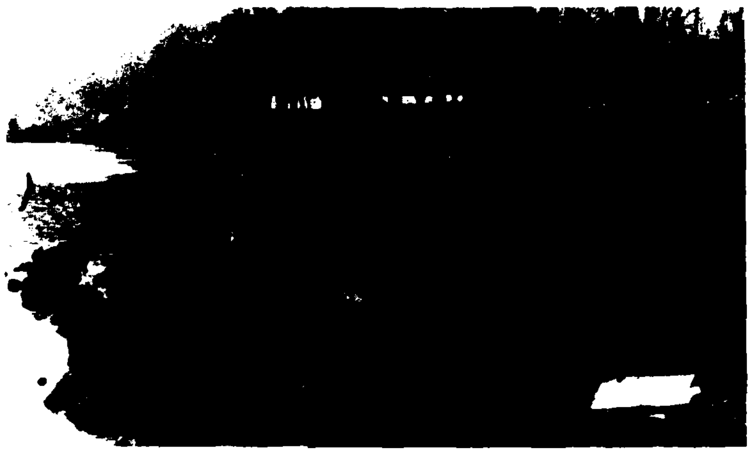


AERIAL VIEW
15 MAY 1979

SCHEME 6 PHOTOS
POWHATAN POINT, OHIO
SITE
OHIO RIVER

PLATE 31

FROM STATION 15+75
25 OCTOBER 1979



FROM STATION 15+75
8 APRIL 1980

FROM STATION 15+75
3 DECEMBER 1980

SCHEME 6 PHOTOS
POWHATAN POINT, OHIO
SITE
OHIO RIVER

PLATE 32

OHIO RIVER
SAINT MARYS, WEST VIRGINIA

Section 32 Program Streambank Erosion Control
Evaluation and Demonstration Act of 1974

OHIO RIVER AT SAINT MARYS, WEST VIRGINIA
DEMONSTRATION PROJECT PERFORMANCE REPORT

I. INTRODUCTION

A. Project Name and Location. Saint Marys, Pleasants County, West Virginia, along the left descending bank below ORM 154.9 with State Coordinate System references of N 509, 470.0 and E 2,365,198.5. Exhibit No. I-1 shows the project location.

B. Authority. Streambank Erosion Control Evaluation and Demonstration Act of 1974, Section 32, P.L. 93-251.

C. Purpose and Scope. This report describes slope failure and erosion condition, types of treatments used and a performance evaluation of a demonstration project on the Ohio River designed and monitored by the Huntington District.

D. Problem Resume. The left bank of the Ohio River approximate to and upstream of Middle Island in the back channel and including a ferry landing was subject to active slope failure and bank erosion with resulting slope distress approximate to residences, a church, and historically significant building foundations and walls.

II. HISTORICAL DESCRIPTION

A. Stream Description, General.

1. Topography. The Ohio River at the demonstration site drains an area including Pennsylvania west of the Allegheny Mountains and portions of Kentucky, Ohio, West Virginia, New York, and Maryland. Major tributaries are the Allegheny and Monongahela Rivers. The topography of the basin is characterized by mature development of the drainage systems within the Kanawha Physiographic Section of the Appalachian Plateau Province. From its origin at Pittsburgh, the river descends 120 feet along a course of 154.9 miles to the demonstration site. Relief at the site is approximately 600 feet from the river to the top of the surrounding valley walls. The river at the demonstration site is in a

back channel. The natural stream gradient is about 0.7 foot per mile. The valley floor is about three-fourth mile in width. The lower reach of upper banks are from 10 feet to 20 feet above normal pool at the St. Marys Project. The St. Marys, West Virginia, demonstration site is located along a narrow alluvium terrace delineated at its up and down stream limits by colluvium and bedrock.

2. Geology. The Ohio River throughout its course along the West Virginia-Ohio border has become entrenched in sedimentary strata of Pennsylvanian and older periods. These strata are made up of interbedded sandstones, siltstones, clay, shales, limestones, and coals. The bedrock valley of the Ohio River contains outwash from the Wisconsin Glacier overlain by recent alluvium. In the portion of the Ohio Valley within the project reach, the outwash is predominantly gravel, and gravelly sand overlain by sand, silty sand and clayey silt. Since the last glacial episode, the Ohio River has been cutting through and laterally into these materials with river terraces remaining as erosional remnants at various elevations in outwash and alluvium and most often by point bar accretion with the forming of a well defined flood plain. In the study area, the Ohio River is still underlain by fill and outwash to depths of approximately 55 feet.

The Ohio River channel has changed location by lateral cutting and filling within the alluvium and outwash which fills the bedrock valley. The channel is, however, often bedrock-controlled at a location on one side of the Pleistocene effects-defined valley. One bank often consists of flood plain deposits and the other of rock outcrop or colluvial soils which have accumulated by weathering, creep, and landslides. The colluvial soils are generally stiff silty clays with angular rock fragments and little or no layering. These soils tend to be somewhat resistant to river-related erosion.

3. Locality, Development, and Occupation. The Ohio River valley in the vicinity of the demonstration site has a diverse urban and industrial land use. Most of these broad floodplains are in agriculture use. Within the Willow Island navigation pool, the river valley contains several small cities including New Martinsville, Paden City, and Sistersville in West Virginia, and New Matamoras in Ohio. Local

industries include coal mining, quarries, chemical production, electric power generation, and light manufacturing. The river is paralleled by railroads and highways located approximate to both banks.

The Ohio River drainage has been an important transportation system since prehistory and has been improved for navigation beginning in 1824 when Congress provided for removal of obstructions such as bars and snags. For many years river navigation use was addressed by open channel improvements only. In addition to removal of channel obstructions, stone training dikes were constructed at various bars to restrict more frequent flows to the defined channel. The first movable dam on the Ohio River was located at Davis Island, 4.7 miles below Pittsburgh, and opened to commerce October 7, 1885. A system of locks and movable dams wsa eventually constructed along the entire Ohio River. In 1918, Lock and Dam 17 was put into operation 12.6 miles downstream of the demonstration site. These early dams incorporated a navigable pass to provide a channel for open river navigation during periods of high flow. A series of wickets, heavy timber shutters, were raised to impound water as needed to maintain a navigation pool. When not required, the wickets would lie flat at such a depth as to offer no obstruction to free navigation through the pass. Replacement of these original navigation dams with fixed, gated structures having higher lifts has been ongoing. In 1975, Willow Island Locks and Dam went into full operation and Lock and Dam 17 was removed.

4. Hydrologic Characteristics. The climate of the site reach and Ohio River is continental with marked contrasts and average annual temperatures of about 54°F and an average annual precipitation of 44" rainfall. The period from 1970 through 1976 was determined to be wetter than average. 1979 was a wet year while 1980 was average and 1981 (from 1 October 1980 to February 1981) was dryer than average. Ice occurs on all rivers and streams in the basin with the Ohio River being froze over for nearly the entire length and at this site in the winters of 1976-77 and 1977-78. Major floods affecting the Ohio River occurred in March 1913, March 1936, January 1937, March 1945, and March 1964.

5. Existing Channel Conditions. The back channel location was described in paragraph II.A.1. The channel location and width-depth

relationships have been relatively stable within historical time.

6. Environmental Considerations. Active farming and old fields are frequently encounterd within the Ohio River floodplain area. The steep hillsides adjacent to the valley floor are primarily undeveloped and consist of second growth woodlands. Within the floodplain, vegetation associated with farming and frequent site disturbance prevails. Along the river bottom land, willow, silver maple, and sycamore occur most frequently. On the hillsides and in areas of bank and slope above ordinary high water, oaks, beech, red maple, ash, black cherry and walnut exist. Nails, spikes, eye bolts, cables and physical damage from river traffic are also evident in some trees.

Fish in the project area include channel catfish, carp, spotted bass, largemouth bass, smallmouth bass, white bass, pumpkinseed, bluegill, white crappie, shiners, perch, skipjacks, gizzard shad, and golden redhorse. Excellent warm-water fisheries have developed at or near the mouths of several of the tributary streams. Area wildlife resources include mourning doves, bobwhite quail, and cottontail rabbits in the approximate agricultural areas, while ruffed grouse and squirrels inhabit the uplands. Whitetailed deer are present in the adjacent uplands and also range into the valley at the site. The Ohio River also provides resting and feeding opportunities for several species of migratory waterfowl. Muskrat, raccoon, and fox are some of the fur animals in the area.

This reach of the river, as with the entire Ohio in general, is exposed to various types of pollution which tend to affect aquatic life and generally detract from the aesthetic value of the river. Organic matter, chemicals, sediment, and colloidal material contribute to somewhat degraded water quality, with seasonal variations also resulting from changes in flow and temperature.

An environmental assessment was prepared in accordance with Section 404(b) of Public Law 92-500. Impacts of construction at the site were addressed in the assessment and the effects of each bank protection scheme were considered, as were total project effects. Modifications to the riverbank during construction will cause localized and minor adverse ecological effects including degraded water quality. Construction of

this project was determined to result in net beneficial environmental effects within the riverbank area.

B. Demonstration Project.

1. Hydrologic Characteristics. Channel cross sections have been determined to be generally consistent as to width-depth relationships and prehistorical features including Middle Island. The river channel in the immediate vicinity of the demonstration project has been subject to sand and gravel dredging. Ice formation in the project area has become significant during unusually severe winters. Ice movement is not a factor in bank erosion at the site.

2. Hydraulic Characteristics. Average velocities have, during frequently occurring excessive flow events, been determined as from 5 to 7 feet per second within the Ohio River channel. At the St. Marys, West Virginia Demonstration Project, velocities for these events would often be less. Waves have been observed and monitored under various wind and traffic conditions. Maximum wave height was approximately two feet. The minimum pool for navigation use is retained at elevation 602 by Willow Island Locks and Dam 7 miles downstream. The dam gates are raised to pass high flows, so that the influence of the dam on the river decreases with increasing flow. The influence of these navigation dams during excessive flow events is insignificant. Prior to the completion of the Willow Island Locks and Dam in 1975, the Ohio River at the demonstration site was maintained at minimum pool elevation 586.6 by Lock and Dam 17. The stage hydrographs for this project site are referenced as Exhibit I-7.

3. Riverbank Description. The riverbank at the demonstration site is approximate to a barge loading and mooring facility and ferry landing and is characterized by moderate height and relatively steep upper slopes. The bank is composed of fine grained alluvium deposited as point bars. These interbedded and interlensing sediments include silty clays overlying silty sands and sands. A typical geotechnical cross section of the project site is referenced as Exhibit I-6.

The area immediately landward of the top of bank has significant relief and is utilized as a park, church, and home sites. Distance to

an adjacent road is from 40 to 60 feet.

Most of the limited failures of banks at this site occurs during flood events and as the river returns to near normal stages. A frequently encountered failure sequence in these alluvium includes internal erosion of sand and silty sand by groundwater flowing out of the riverbank, referenced as "piping" with resultant weakening of overlying soils. The bank and upper slope then fails by drawdown-related slumpages as the river falls from flood stages with current-related erosion of in situ soils and the failed debris.

The District has been aware of bank and slope conditions at this site since historical times and inclusive of the channelization period. Photographs submitted as Exhibit Nos. II-1 thru II-7 indicate the condition of the bank prior to construction, during construction, and after construction of the demonstration project.

III. DESIGN AND CONSTRUCTION

A. General. The St. Marys, West Virginia, site was used to evaluate three different schemes of bank protection along a reach of somewhat variable upper bank topography.

B. Basis for Design. Treatments were intended to generally address normal pool land-water interface contacts with upslope conditions being considered at some test sections. These materials were not intended to protect against mechanisms which are most significant and occur during major storms and floods.

The structural features included tire mats, transverse dikes, and stacked tires. Placement of the protections utilizing tires was somewhat labor intensive but was included as being feasible for use by small property owners with limited financial resources. Vegetation covers included grasses.

C. Construction Details. Tire mattress and tire mats, dumped stone transverse dikes, and reinforced concrete filled tire walls were placed

as indicated on Exhibit Nos. I-2 thru I-4. Treatments were completed in 1980 and included the following:

Scheme A - Lower reach of upper bank protected with tire mats and with tire mattress.

Scheme B - Dikes of dumped stone to elevation 604.0

Scheme C - Upper bank buttressed and protected with stacked tire wall.

D. Costs. These treatments were constructed during the period from September 1980 thru December 1980. Total cost including monies to construct was $397,200. A cost summary for each test section, showing cost per lineal foot and cost per square foot, is included as Exhibit No. I-5.

IV. PERFORMANCE OF PROTECTION

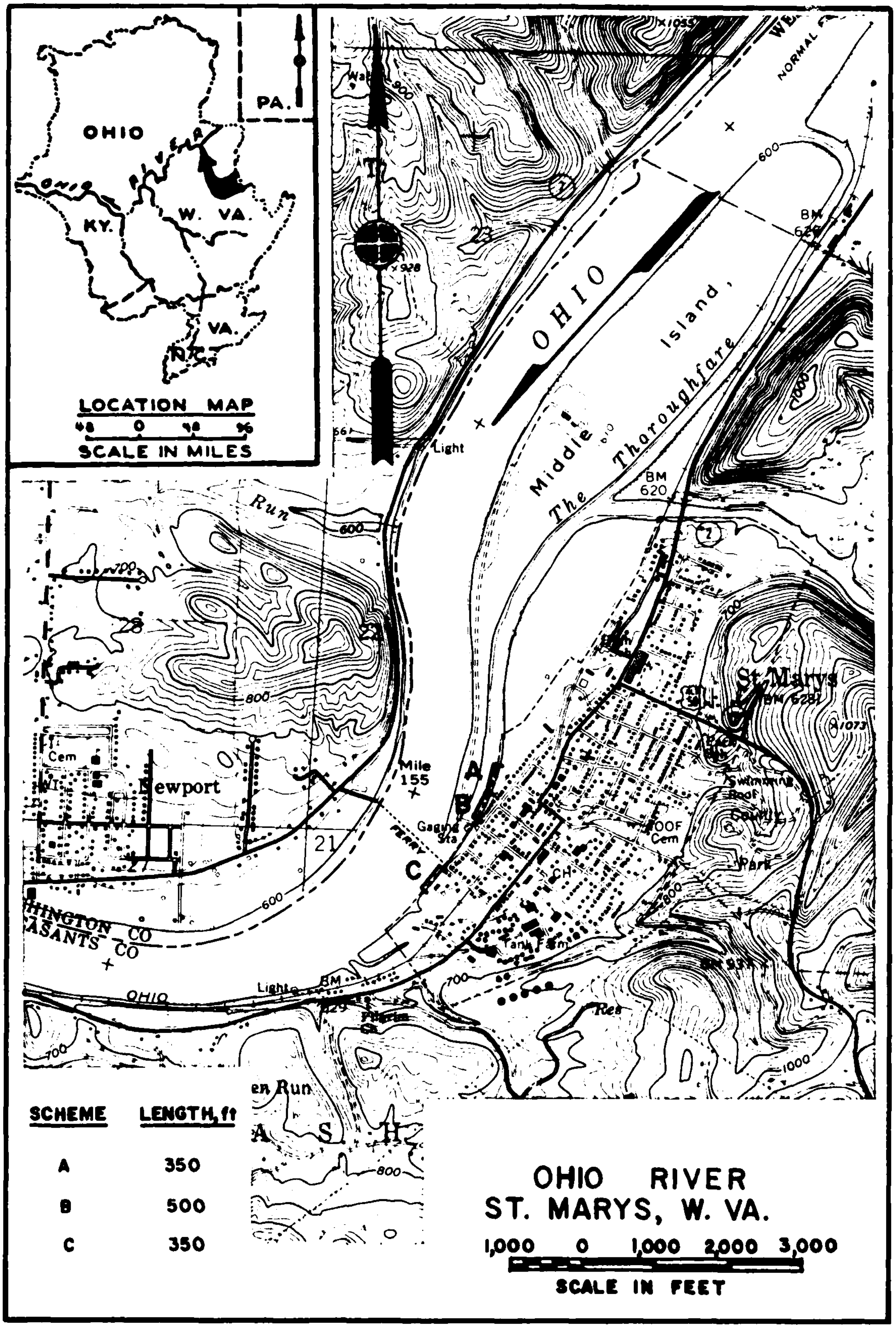
A. Monitoring Program. Monitoring included reach of river and site specific reconnaissance, photography, mapping, sampling, and evaluations. Piezometers were installed in June 1981 and readings are scheduled to begin in July 1981. Sequential and referenced photographs for this site are included as Exhibit No. II. Site location maps, plans, reference points, sections, profiles, and details are included as Exhibit No. I.

B. Evaluation of Protection Performance. The transverse dikes are intended to trap sediments. The tire wall should provide increased stability for approximate banks and slopes. Post construction monitoring data is not sufficient to evaluate the effectiveness of these treatments.

C. Rehabilitation. No rehabilitation work has been performed.

D. Summary of Findings. Section A, the upstream treatment, consists of a tire mat. Some distress is noted and attributed to rather steep

slopes within this area; however, loss of bank materials by failure erosion has most probably been reduced. The downstream adjacent treatment, Section B, consists of dikes with their effect on adjacent slope instability conditions being considered as beneficial. Section C, the most downstream treatment, consists of tire walls which have experienced some loss of fine granular backfill during storm and excessive flow events but are performing satisfactorily in effecting a reduction in bank failure and erosion.



PA.
OHIO
KY.
W. VA.
VA.
N.C.
LOCATION MAP
48 0 48 96
SCALE IN MILES
OHIO
Middle Island,
The Thoroughfare
Light
BM 620
Run
Newport
Cem
Mile 155
A
B
C
Gaging Sta
FERRY
St. Marys
BM 628
Swimming Pool
Park
CH
Tank Farm
IOOF Cem
Res
Light
OHIO
WASHINGTON CO
PLEASANTS CO
SCHEME
LENGTH, ft
A 350
B 500
C 350
OHIO RIVER
ST. MARYS, W. VA.
1,000 0 1,000 2,000 3,000
SCALE IN FEET

EXHIBIT I-1

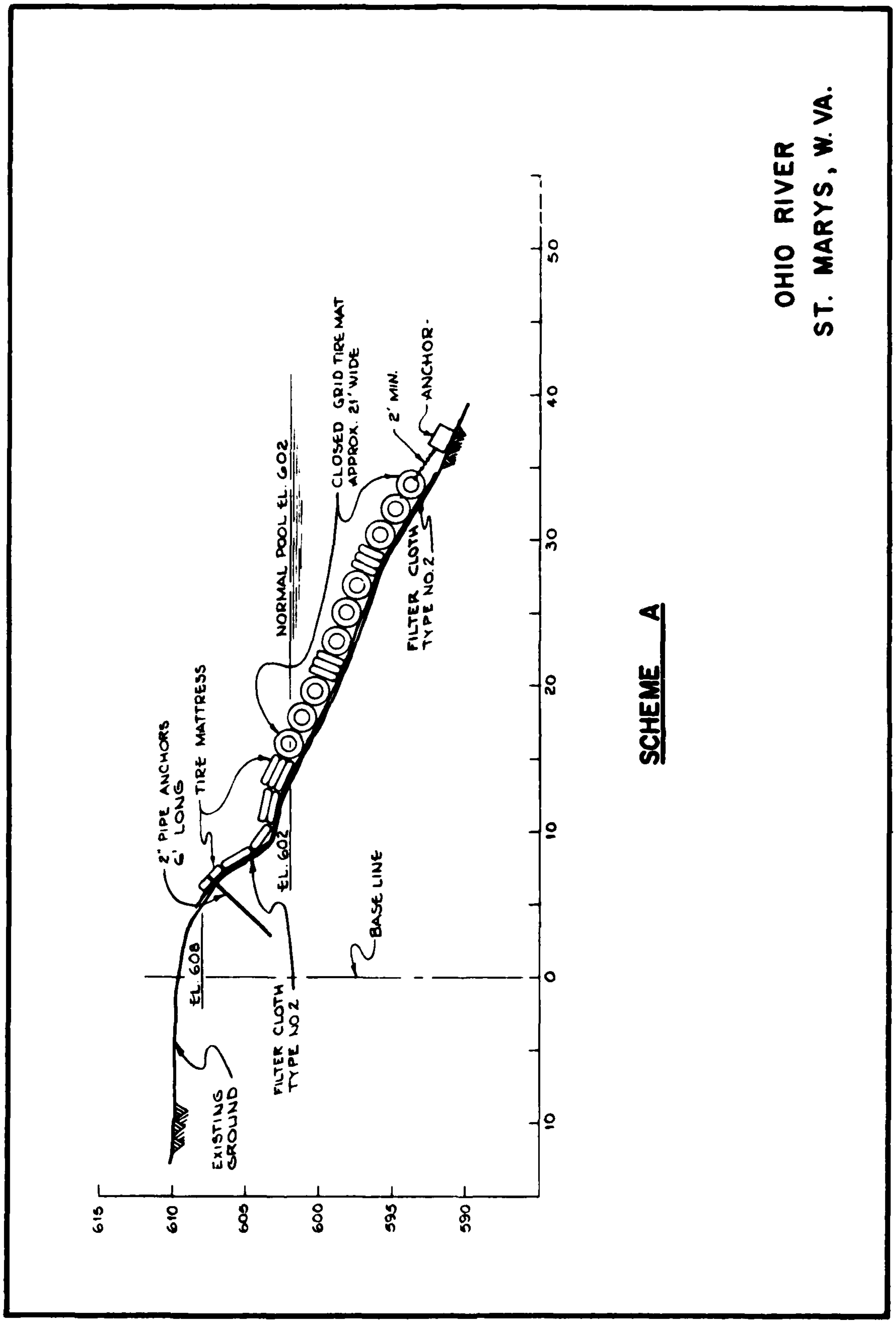

OHIO RIVER
ST. MARYS, W. VA.
SCHEME A
NORMAL POOL EL. 602
CLOSED GRID TIRE MAT
APPROX. 21' WIDE
2' MIN.
ANCHOR
FILTER CLOTH
TYPE NO. 2
TIRE MATTRESS
2" PIPE ANCHORS
6' LONG
EL. 602
EL. 608
BASE LINE
FILTER CLOTH
TYPE NO. 2
EXISTING
GROUND
615
610
605
600
595
590
10
0
10
20
30
40
50

EXHIBIT I-2

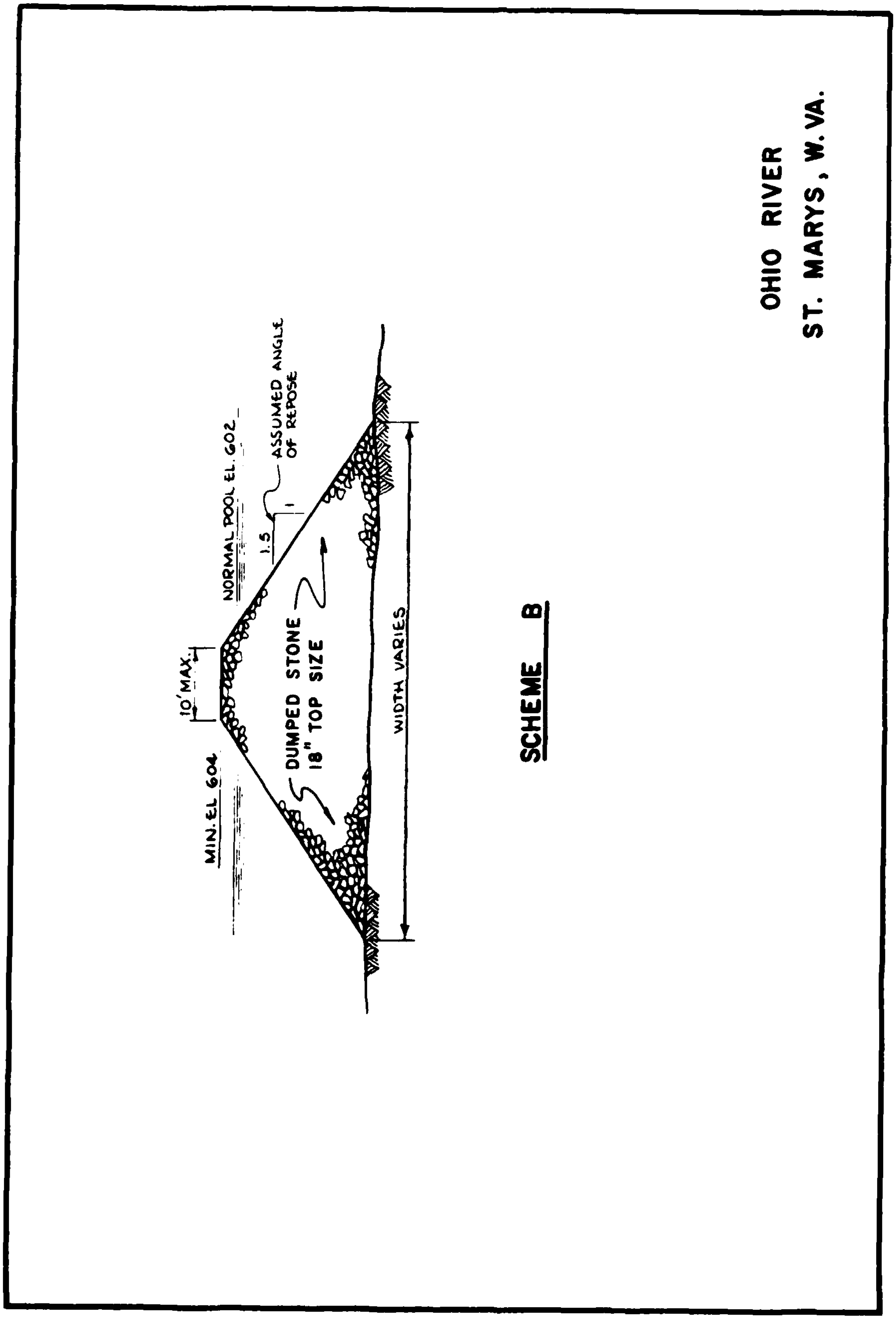

OHIO RIVER
ST. MARYS, W. VA.
SCHEME B
MIN. EL 604
10' MAX.
NORMAL POOL EL. 602
ASSUMED ANGLE OF REPOSE
1
1.5
DUMPED STONE
18" TOP SIZE
WIDTH VARIES

EXHIBIT I-3

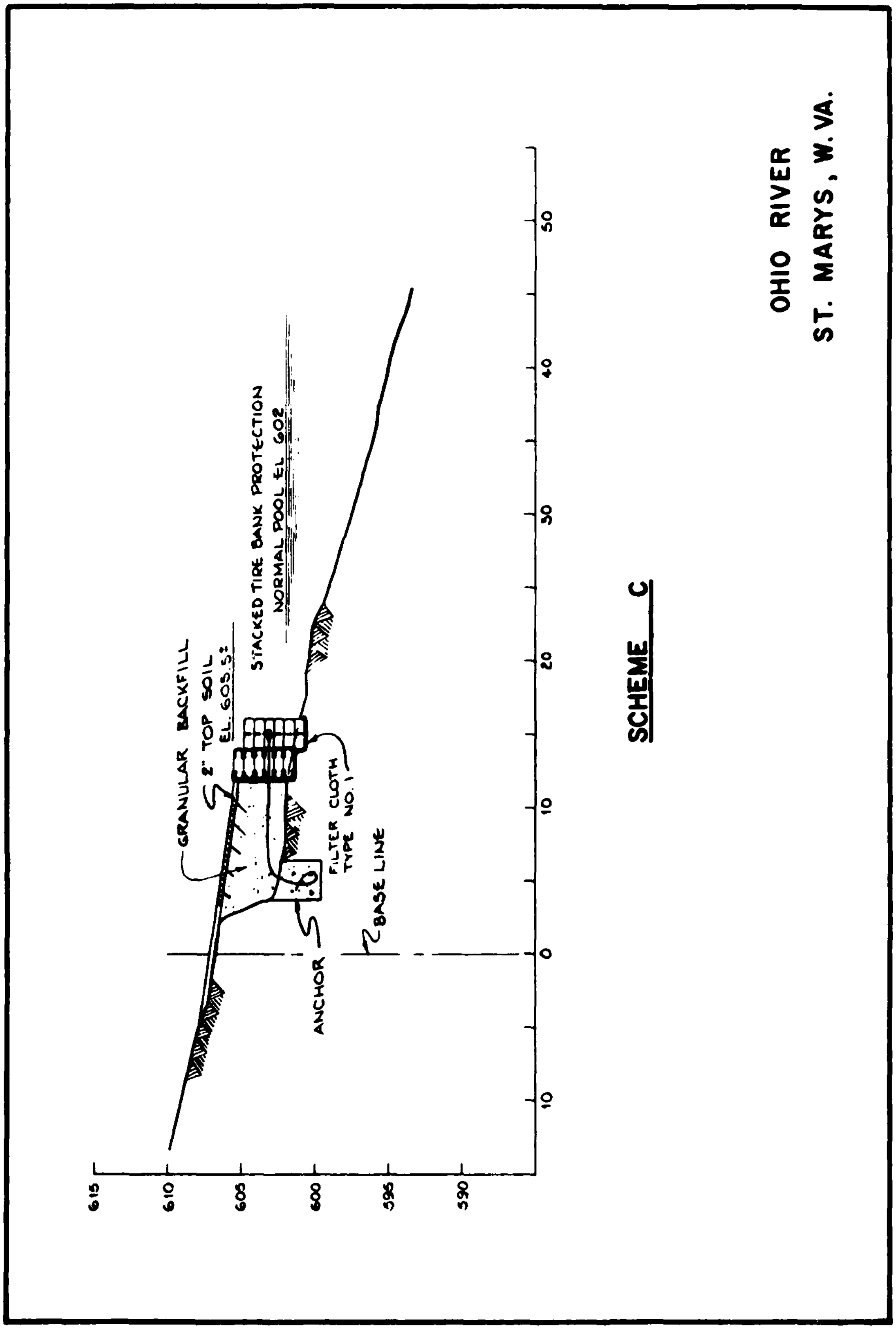

OHIO RIVER
ST. MARYS, W. VA.
SCHEME C
GRANULAR BACKFILL
2" TOP SOIL
EL. 605.5±
STACKED TIRE BANK PROTECTION
NORMAL POOL EL 602
FILTER CLOTH
TYPE NO. 1
BASE LINE
ANCHOR
615
610
605
600
595
590
10
0
10
20
30
40
50

EXHIBIT I-4

COST SUMMARY
ST. Marys, W. Va., Demonstration Project

ITEM	TOTAL COST	COMMENTS
Construction	$ 292,520	Construction work done by lump sum contract
Engineering & Design	71,130	
Supervision & Administration	33,090	
Monitoring	460	
Reconstruction	0	
TOTAL	$ 397,200	

CONSTRUCTION COST FOR EACH TREATMENT

Type of Protection		Cost per Lineal foot	Cost per Square Foot
Scheme A:	tire mat	$ 159.02	$ 4.54
Scheme B:	dikes	399.52	6.66
Scheme C:	tire wall	106.01	5.30

These costs include all preparation of slopes and installation

EXHIBIT I-5

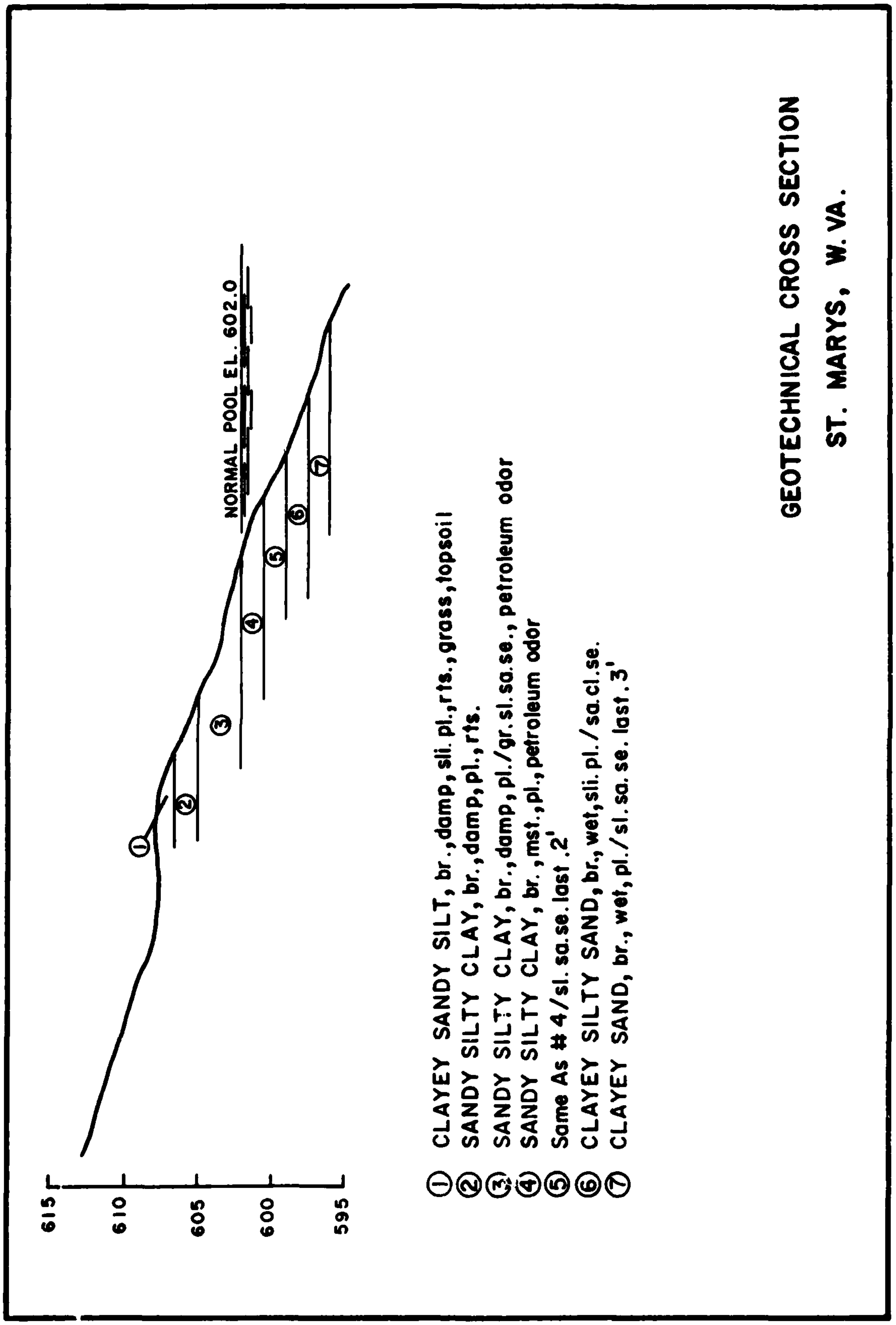


EXHIBIT I-6 (SHEET 1 OF 2)

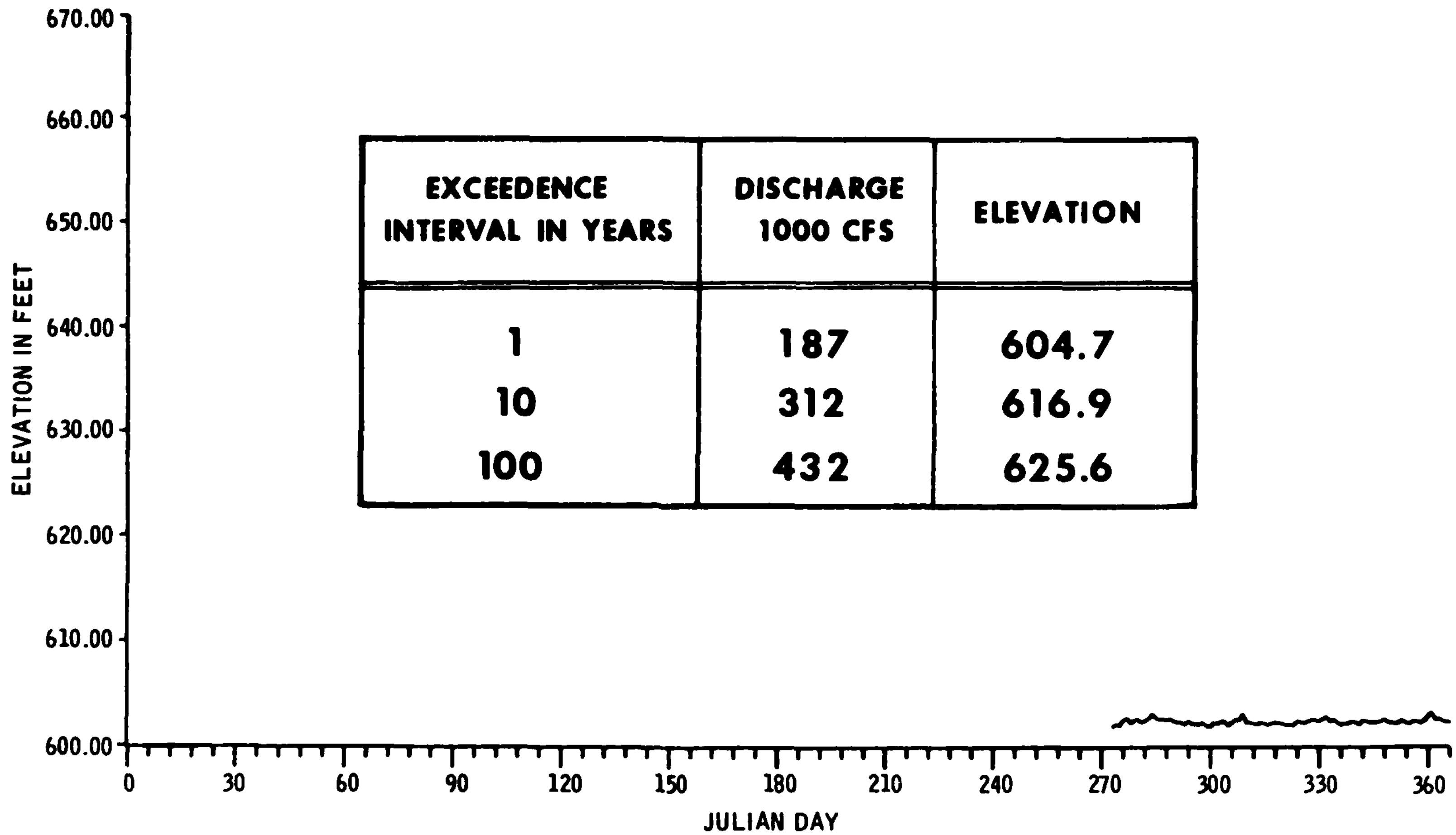
ABBREVIATIONS

a.	angle
alt.	alternat(e)(ly)(ing)
amt.	amount
ang.	angular
approx.	approximate(ly)
ar.	argillaceous
aren.	arenaceous
asp.	asphaltic
b.	bone
ba.	banded(ing)
bd.	bed(ded)(ing)
bdr.	bedrock
bf.	buff
bk.	black
bky.	blocky
bkn.	broken
bl.	blue
bou.	boulder(s)
bre.	breccia(ted)
br.	brown
c.	coarse
ca.	calcareous
carb.	carbonaceous
cav.	cavern, cavity
cbl.	cobble(y)
ch.	chert
cl.	clayey
cle.	clean
coa.	coated(ing)
comp.	compact
conc.	concretion
cong.	conglomeratic
cont.	contains
cr.	crushed
crm.	crumbly
cst.	crystal(line)
cem.	cement(ed)
di.	dirty
dia.	diameter
diag.	diagonal
dis.	disintegrated
disc.	discontinuous
diss.	disseminated
dk.	dark
dn.	dense
dmp.	damp
ext.	extremely
f.	fine
fer.	ferruginous
fis.	fissile
fil.	filled(ing)
fos.	fossil(iferous)
frac.	fracture(d)
frags.	fragment(s)(al)
fri.	friable
f.w.	free water
g.	grain(ed)
gen.	generally
gn.	green
gr.	gray
gra.	gravelly
grad.	grading(ed)
G.W.	ground water
h.	hard
ha.	high angle
hi.	high(ly)(er)
hor.	horizontal(ly)
inc.	inclusions
incr.	increasing(ly)
inla.	interlaminated
intbd.	interbedded
irr.	irregular
jt.	joint(ed)
l.	little
la.	low angle
las.	laminat(ions)(ed)
lay.	layer(s)
le.	lean
lea.	leached
len.	lense(s)
lg.	large
lt.	light
m.	moderate(ly)
ma.	many
mas.	massive(ly)
mat.	material
mic.	micaceous
min.	mineralized
mos.	mostly
mot.	mottled
mst.	moist
mtx.	matrix
n.	near
nod.	nodule(s)
num.	numerous
o.	open
occ.	occasional(ly)
occu.	occurring
org.	organic
pa.	parting(s)
part.	particle(s)
pl.	plastic
peb.	pebble(s)
pk.	pink
pkt.	pocket(s)
pit.	pit(ted)
pn.	plane(s)
po.	porous
pt.	part(ly)
pyr.	pyrite(ic)
q.	quartzitic
r.	red
ro.	rock(s)
rot.	rotten(ed)
rou.	round(ed)
rt.	root(s)(let)
s.	soft
sa.	sandy
sat.	saturated
scat.	scattered
se.	seams
sev.	severely
sevr.	several
sh.	shaly
sil.	siliceous
sl.	silty
sli.	slight(ly)
slk.	slickensided
sm.	small
so.	some
sol.	solution
sta.	stain(ed)
stf.	stiff
stks.	streak(s)
str.	stringer(s)
sty.	stylolite(ic)
t.	thin
tho.	throughout
tk.	thick
tr.	trace
v.	variably
va.	variegated
ve.	very
veg.	vegetation
ver.	vertical(ly)
vu.	vuggy
w.	water
/	with
w.c.	water content
wd.	weathered
whi.	white
x-bd.	cross bedded(ing)
y.	yellow
zo.	zone

GEOTECHNICAL CROSS SECTION

EXHIBIT I-6 (SHEET 2 OF 2)

1979



EXCEEDENCE INTERVAL IN YEARS	DISCHARGE 1000 CFS	ELEVATION
1	187	604.7
10	312	616.9
100	432	625.6

OHIO RIVER
STAGE HYDROGRAPHS AT ST. MARYS, WEST VIRGINIA

EXHIBIT I-7 (SHEET 1 OF 3)

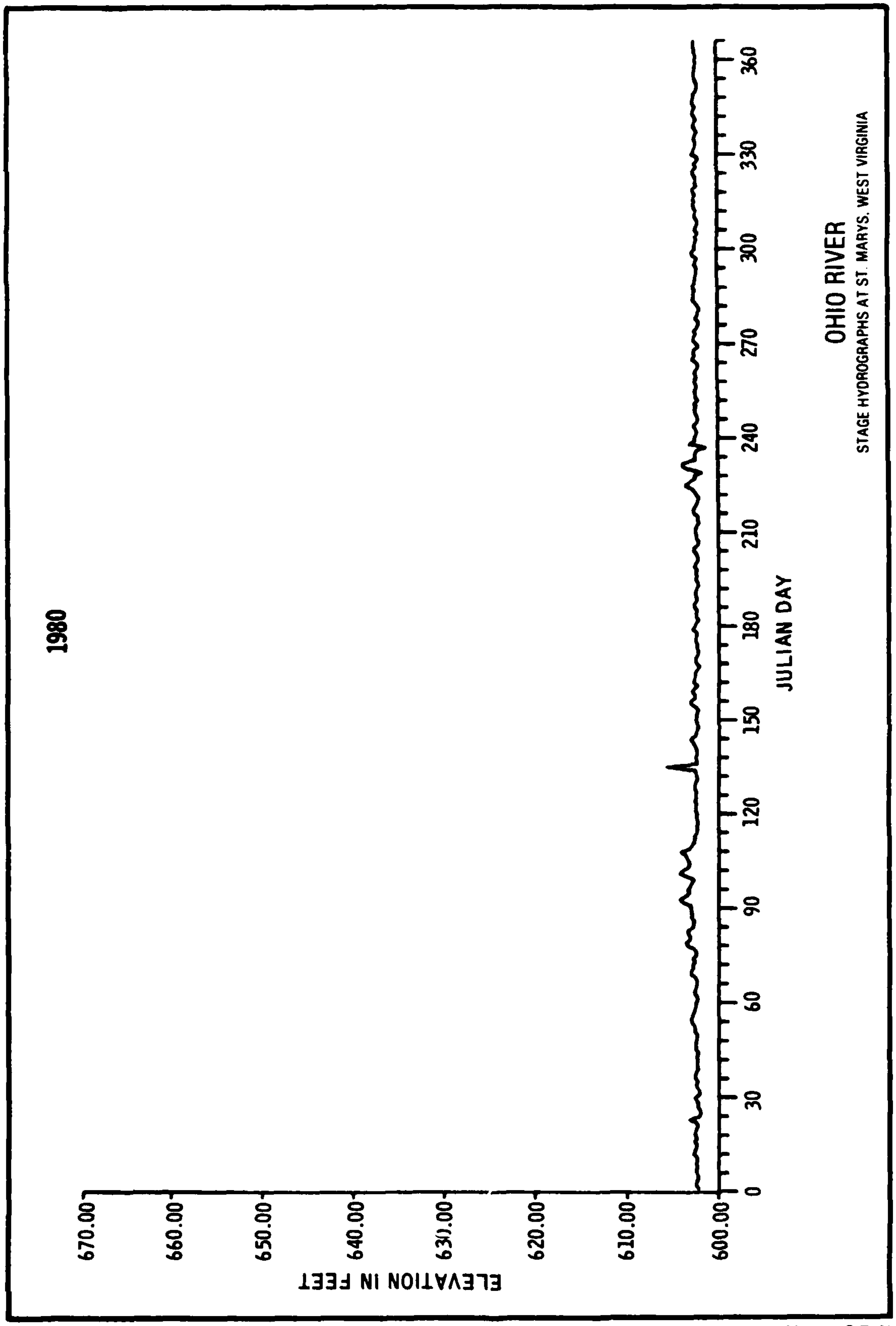


EXHIBIT I-7 (SHEET 2 OF 3)

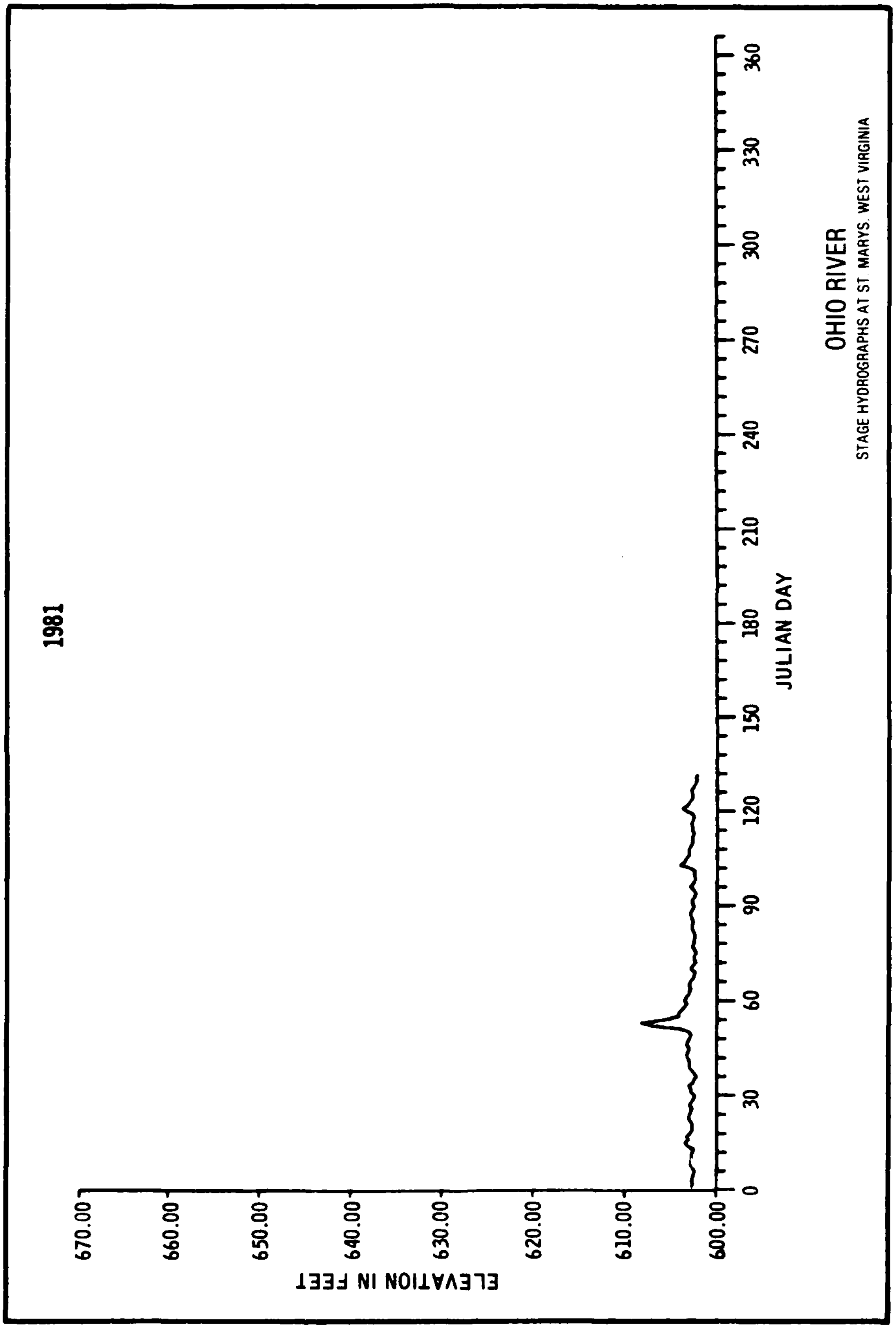
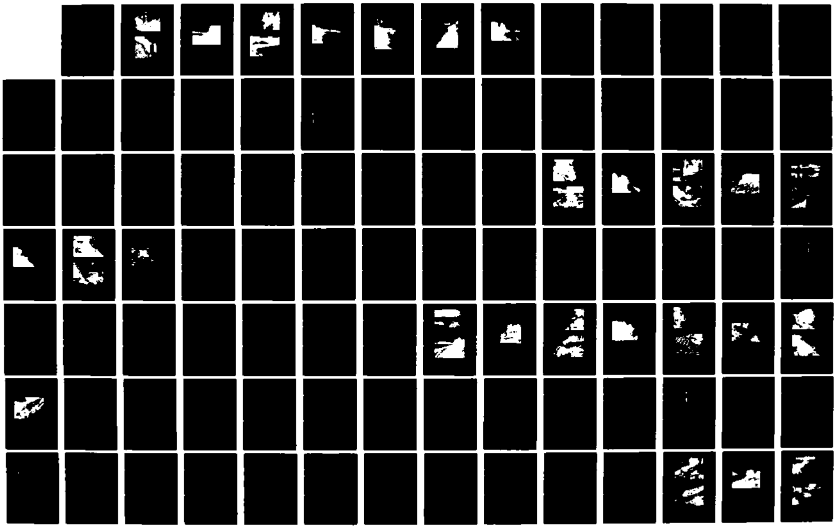
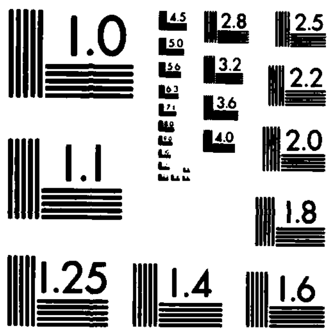


EXHIBIT I-7 (SHEET 3 OF 3)

AD-A121 134 THE STREAMBANK EROSION CONTROL EVALUATION AND DEMONSTRATION ACT OF 1974 S..(U) ARMY ENGINEER WATERWAYS EXPERIMENT STATION VICKSBURG MS HYDRA.. 3/4

UNCLASSIFIED M P KEOWN ET AL. DEC 81 WES/TR/H-77-9-APP-D F/G 13/2 NL





MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A

SCHEME A: LOOKING UPSTREAM BEFORE CONSTRUCTION

SCHEME A: LOOKING DOWNSTREAM DURING CONSTRUCTION

EXHIBIT II-1

SCHEME A: LOOKING UPSTREAM AFTER CONSTRUCTION

EXHIBIT II-2

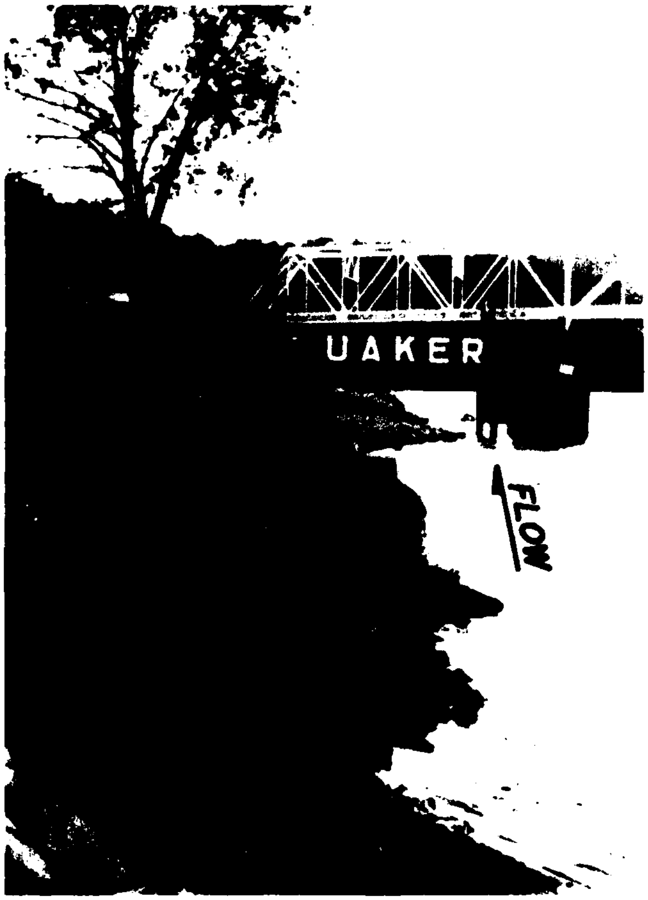
SCHEME B: LOOKING UPSTREAM BEFORE CONSTRUCTION

SCHEME B: LOOKING DOWNSTREAM DURING CONSTRUCTION

EXHIBIT II-3

SCHEME B: LOOKING DOWNSTREAM AFTER CONSTRUCTION

EXHIBIT II-4



SCHEME C: LOOKING DOWNSTREAM BEFORE CONSTRUCTION

EXHIBIT II-5

SCHEME C: LOOKING DOWNSTREAM DURING CONSTRUCTION

EXHIBIT II-6

SCHEME C: LOOKING UPSTREAM AFTER CONSTRUCTION

EXHIBIT II-7

OHIO RIVER
RAVENSWOOD, WEST VIRGINIA

Section 32 Program Streambank Erosion Control
Evaluation and Demonstration Act of 1974

OHIO RIVER AT RAVENSWOOD, WEST VIRGINIA
DEMONSTRATION PROJECT PERFORMANCE REPORT

I. INTRODUCTION

A. Project Name and Location. Ravenswood, Jackson County, West Virginia, along the left descending bank at and for a 1600 foot reach below ORM 220.5 with State Coordinate System references of N 346,239.9 and E 2,208,723.4. Exhibit No. I-1 shows the project location.

B. Authority. Streambank Erosion Control Evaluation and Demonstration Act of 1974, Section 32, P.L. 93-251.

C. Purpose and Scope. This report describes a bank failure and erosion condition, types of treatments used, and a performance evaluation of a demonstration project on the Ohio River designed and monitored by the Huntington District.

D. Problem Resume. The left bank of the Ohio River approximate and upstream of Sandy Creek and including a ferry landing was subject to active failure and erosion with resulting *top of slope* retreat and variable encroachment on city park lands and road right of way, State Department of Highways aggregate stockpiles, and on residential and small commercial properties.

II. HISTORICAL DESCRIPTION

A. Stream Description, General.

1. Topography. The Ohio River at the demonstration site drains an area including Pennsylvania west of the Allegheny Mountains and portions of Kentucky, Ohio, West Virginia, New York, and Maryland. Major tributaries are the Allegheny, Monongahela, Beaver, Muskingum, Little Kanawha, Hocking, and Shade Rivers. The topography of the basin is characterized by mature development of the drainage systems within the Kanawha Physiographic Section of the Appalachian Plateau Province. From its origin at Pittsburgh, the river descends 160 feet along a course of 220.5 miles to the demonstration site. Relief at the site is

approximately 1000 feet from the river to the top of the surrounding valley walls. The river flows at the demonstration site following a course with curves of 45 degrees and radii of 5 miles. The natural stream gradient is about 0.7 foot per mile. The valley floor is about one anu one-fourth miles in width. Stream bank heights are from 10 feet to 20 feet above normal pool at the Ravenswood Project. The Ravenswood, West Virginia, demonstration site is located along a relatively wide alluvium terrace delineated at its up and down stream limits by colluvium and bedrock.

2. Geology. The Ohio River throughout its course along the West Virginia-Ohio border has become entrenched in sedimentary strata of Pennsylvanian and older periods. These strata are made up of interbedded sandstones, siltstones, clay, shales, limestones, and coals. The bedrock valley of the Ohio River contains outwash from the Wisconsin Glacier overlain by recent alluvium. In the portion of the Ohio Valley within the project reach, the outwash is predominantly gravel, sand and gravel, and gravelly sand overlain by sand, silty sand and clayey silt. Since the last glacial episode, the Ohio River has been cutting through and laterally into these materials with river terraces remaining as erosional remanents at various elevations in outwash and alluvium and most often by point bar accretion with the forming of a well defined flood plain. In the study area, the Ohio River is still underlain by fill and outwash to depths of approximately 55 feet.

The Ohio River channel has changed location by lateral cutting and filling within the alluvium and outwash which fills the bedrock valley. The channel is, however, often bedrock controlled at its location on one side of the Pleistocene effects-defined valley. One bank often consists of flood plain deposits and the other rock outcrop or colluvial soils which have accumulated by weathering, creep, and landslides. The colluvial soils are generally stiff silty clays with angular rock fragments and little or no layering. These soils tend to be somewhat resistant to river-related erosion.

3. Locality, Development, and Occupation. The Ohio River valley

in the vicinity of the demonstration site has a diverse and urban industrial land use. Most of these broad floodplains are in agriculture use. Within the Racine navigation pool the river valley contains several small cities including Millwood, Parkersburg, Williamstown in West Virginia and Hockingport and Belpre in Ohio. Local industries include coal mining, quarries, aluminum, alloys and chemical production, electric power generation, and light manufacturing. The river is paralleled by railroads and highways located approximate to both banks.

The Ohio River drainage has been an important transportation system since prehistory and has been improved for navigation beginning in 1824 when Congress provided for removal of obstructions such as bars and snags. For many years river navigation use was addressed by open channel improvements only. In addition to removal of channel obstructions, stone training dikes were constructed at various bars to restrict more frequent flows to the defined channel. The first movable dam on the Ohio River was located at Davis Island, 4.7 miles below Pittsburgh, and opened to commerce October 7, 1885. A system of locks and movable dams was eventually constructed along the entire Ohio River. In 1918, Lock and Dam 22 was put into operation 0.4 mile downstream of the demonstration site. These early dams incorporated a navigable pass to provide a channel for open river navigation during periods of high flow. A series of wickets, heavy timber shutters, were raised to impound water as needed to maintain a navigation pool. When not required, the wickets would lie flat at such a depth as to offer no obstruction to free navigation through the pass. Replacement of these original navigation dams with fixed, gated structures having higher lifts has been ongoing. In 1969, Racine Locks and Dam went into full operation and Lock and Dam 22 was removed.

4. Hydrologic Characteristics. The climate of the site reach and Ohio River is continental with marked contrasts and average annual temperatures of about 54°F and an average annual precipitation of 44" rainfall. The period from 1970 through 1976 was determined to be wetter than average. 1979 was a wet year while 1980 was average and 1981 (from 1 October 1980 to February 1981) was dryer than average. Ice occurs on

all rivers and streams in the basin with the Ohio River being froze over for nearly the entire length and at this site in the winters of 1976-77 and 1977-78. Major floods affecting the Ohio River occurred in March 1913, March 1936, January 1937, March 1945, and March 1964.

5. Existing Channel Conditions. The sinuosity of the channel was described in paragraph II.A.1. The channel location and width-depth relationships have been relatively stable within historical time. Buffington Island is located 2.5 miles upstream of the Ravenswood Project. A velocity profile and channel cross section is included as Exhibit I-8.

6. Environmental Considerations. Active farming and old fields are frequently encounterd within the Ohio River floodplain area. The steep hillsides adjacent to the valley floor are primarily undeveloped and consist of second growth woodlands. Within the floodplain, vegetation associated with farming and frequent site disturbance prevails. Along the river bottom land, willow, silver maple, and sycamore occur most frequently. On the hillsides and in areas of bank and slope above ordinary high water, oaks, beech, red maple, ash, black cherry and walnut exist. Nails, spikes, eye bolts, cables and physical damage from river traffic are also evident in many specimens.

Fish in the project area include channel catfish, carp, spotted bass, largemouth bass, smallmouth bass, white bass, pumpkinseed, bluegill, white crappie, shiners, perch, skipjacks, gizzard shad and golden redhorse. Excellent warm-water fisheries have developed at or near the mouths of several of the tributary streams. Area wildlife resources include mourning doves, bobwhite quail, and cottontail rabbits in the approximate agricultural areas, while ruffed grouse and squirrels inhabit the uplands. Whitetailed deer are present in the adjacent uplands and also range into the valley at the site. The Ohio River also provides resting and feeding opportunities for several species of migratory waterfowl. Muskrat, raccoon, and fox are some of the fur animals in the area.

This reach of the river, as with the entire Ohio in general, is exposed to various types of pollution which tend to affect aquatic life and generally detract from the aesthetic value of the river. Organic matter, chemicals, sediment, and colloidal material contribute to somewhat degraded water quality, with seasonal variations also resulting from changes in flow and temperature.

An environmental assessment was prepared in accordance with Section 404(b) of Public Law 92-500. Impacts of construction at the site were addressed in the assessment and the effects of each bank protection scheme were considered, as were total project effects. Modifications to the riverbank during construction will cause localized and minor adverse ecological effects including degraded water quality. Construction of this project was determined to result in net beneficial environmental effects within the riverbank area.

B. Demonstration Project.

1. Hydrologic Characteristics. Channel cross sections have been determined to be generally consistent as to width-depth relationships and pre-historical features including Buffington Island. The river channel in the immediate vicinity of the demonstration project has been subject to sand and gravel dredging. Ice formation in the project area has become significant during unusually severe winters. Ice movement is not a factor in bank erosion at the site.

2. Hydraulic Characteristics. Average velocities have, during frequently occurring excessive flow events, been determined as from 5 to 7 feet per second within the Ohio River channel. Waves have been observed and monitored under various wind and traffic conditions. Maximum wave height was approximately two feet. The minimum pool for navigation use is retained at elevation 560 by the Racine Locks and Dam 17 miles downstream. The dam gates are raised to pass high flows, so that the influence of the dam on the river decreases with increasing flow. The influence of these navigation dams during excessive flow

events is insignificant. Prior to the completion of the Racine Locks and Dam in 1969, the Ohio River at the demonstration site was maintained at minimum pool elevation 551.4 by Lock and Dam 22. The stage hydrographs for the project site are referenced as Exhibit I-9.

3. Riverbank Description. The riverbank at the demonstration site is approximate to barge loading and mooring facility and ferry landing and includes fill and an abandoned road and is characterized by moderate height and variable slopes. The bank is composed of fine grained alluvium deposited as point bars and during overbank event falling stages. These interbedded and interlensing sediments include silty clays overlying silty sands and sands. In the project reach of bank, dump debris and random filling are frequently encountered. A typical geotechnical cross section of the project site is referenced as Exhibit I-7.

The area immediately landward of the top of bank has low relief and is utilized as a park, for aggregate stockpiling, and home sites. Distance to an adjacent road is from 60 to 80 feet.

Most failure of banks at this site occurs during flood events and as the river returns to near normal stages. A frequently encountered failure sequence in these alluvium includes internal erosion of sand and silty sand by groundwater flowing out of the riverbank, referenced as "piping" with resultant weakening of overlying soils. The bank then fails by drawdown related slumpages as the river falls from flood stages with current-related erosion of in situ soils and the failed debris.

The District has been aware of bank failure and erosion at this site since historical times and inclusive of the channelization period. Photographs submitted as Exhibit Nos. II-1 thru II-8 indicate the condition of the bank prior to construction, during construction, and after construction of the demonstration project.

III. DESIGN AND CONSTRUCTION

A. General. The Ravenswood, West Virginia, site was used to evaluate four different schemes of bank protection along a reach of quite

variable upper bank topography. Regrading of failure and erosion-defined bank topography was effected at some test sections.

B. Basis for Design. Treatments were intended to generally address normal pool land-water interface contacts with upslope conditions being considered at some test sections. These materials were not intended to protect against mechanisms which are most significant and occur during major storms and floods. The structural features included a breakwater fence, Longard Tube and gabions and gravel overlying quarry run rock which are locally available materials. Placement of breakwater fences, gabions, and graded gravel and quarry run rock was somewhat labor intensive but were included as being feasible for use by small property owners with limited financial resources. Vegetation covers included grasses and purpleosier willow cutting.

C. Construction Details. A breakwater fence, gabions, quarry run fill, and Longard Tube treatments were placed as indicated on Exhibit Nos. I-2 thru I-5. Treatments were completed in 1977 and included the following materials:

Scheme A - Lower reach of upper bank protected by breakwater fences with four different board sizes and spaces.

Scheme B - Toe of upper bank protected with firebrick filled gabions.

Scheme C - Upper bank toe protection using six-inch top size quarry run stone.

Scheme D - Placement of a Longard Tube approximate to the area of normal pool land-water contacts.

D. Costs. These treatments were constructed by August 1977. Total cost including monies to construct was $205,750. A cost breakdown for each test section, showing cost per lineal foot and cost per square foot, is included as Exhibit No. I-6.

IV. PERFORMANCE OF PROTECTION

A. Monitoring Program. Monitoring included reach of river and site specific reconnaissance, photography, mapping, sampling, and evaluations. Piezometers were installed in June 1981 and readings are scheduled to begin in July 1981. Sequential and referenced photographs for this site are included as Exhibit No. II. Site location maps, plans, reference points, sections, profiles, and details are included as Exhibit No. I.

B. Evaluation of Protection Performance.

1. General. All treatments have most probably reduced erosive losses of bank materials. At bank treatments, failure conditions were observed to occur at and above the protections and in upper bank areas. Frequently encountered failure conditions in these alluvium materials have been referenced. Additionally, bank failure and soil removal mechanisms considered in the development of design concepts for treatment alternatives which are not generally significant are: wind-induced and navigation-generated waves and weather conditions (rainfall impact and runoff, and freeze and thaw cycles)

2. Scheme A. The breakwater fence is damaged by river ice and navigation. Upper bank piped openings and drawdown-related scarps of limited area extent have occurred during the post-construction period.

3. Scheme B. Gabions have become misaligned and the upper bank materials, including bricks and roof slate have continued to erode by piping.

4. Scheme C. The quarry run rock and gravel do not evidence displacement or deterioration. The ungraded upper bank has continued to erode by piping, related slabbing, and drawdown initiated slumpages.

5. Scheme D. The Longard Tube, though frequently vandalized, has been effective. The upper bank has limited areas of erosion as a result of seasonally persistent seepages.

C. Rehabilitation. This work at the Ravenswood, West Virginia, Project has consisted of filling and patching reaches of the Longard Tube.

D. <u>Summary of Findings</u>. The bank treatments consist of a variety of structural and stone materials. Within the upstream treatment Section A the breakwater fence has been damaged by river ice and tow impacts and is breached at several locations. Corrugated metal pipe drainage systems have been damaged by tow impact. The City of Ravenswood has dumped concrete debris for a reach back of the breakwater fence. It has been determined that this treatment is ineffective against significant bank failure and erosion mechanisms at this site including piping and drawdown related slumpage and, in fact, provides an inadequate section for determining effective protection against wave effects. Back of bank conditions include piping and drawdown failure defined slopes with willow planted at the completion of construction. It is recommended that the breakwater fence be removed and that a properly graded stone protection be placed in the lower bank for this reach. Grass cover has been established for this reach of bank. Section B consists of firebrick-filled filter cloth backed gabions with some misalignment and distress being noted and upper bank piping evident. No reconstruction is required of this treatment at this time and the treatment at the point where it intercepts seepage exit locations appears to be reducing bank failure and erosion. Section C, immediately downriver of the ferry landing, consists of a graded Vanport Limestone and is performing satisfactorily while upper bank areas which were not regraded nor protected are failing and eroding with resulting top of bank retreat. Section D consists of a Longard Tube installation which though frequently vandalized has proved effective in limiting bank failure and erosion. This treatment extends 50-feet up Sandy Creek and is in place requiring no reconstruction efforts. Treatments B, C and D have resulted in reduced bank failure and erosion and have allowed the establishment of volunteer vegetation cover including for the Longard Tube reach a substantial cover of young sycamore. In the reach of the Longard Tube, off bank sand alluvium has accumulated on the subaqueous filter cloth protection.

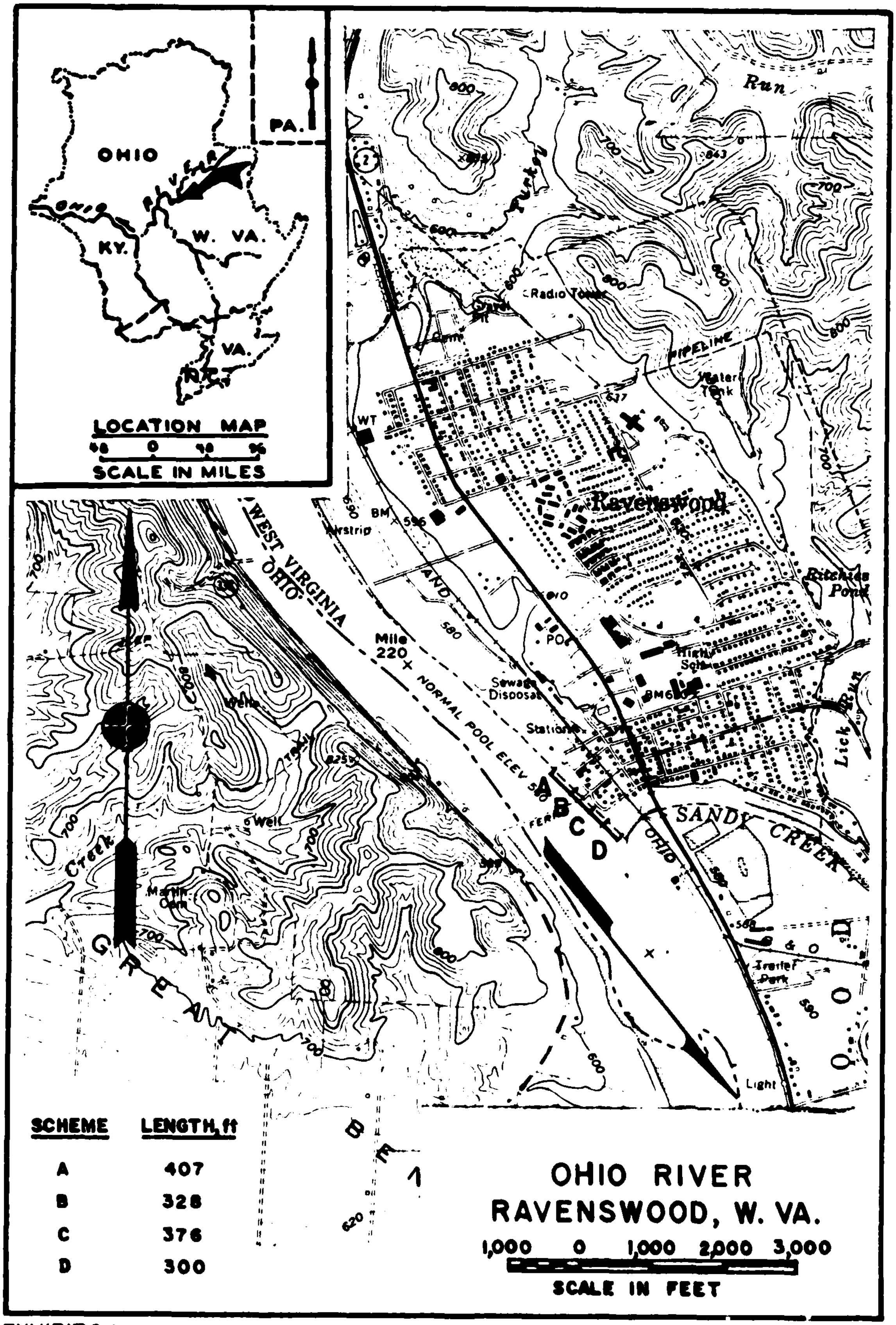

PA.
OHIO
OHIO RIVER
KY.
W. VA.
VA.
N.C.
LOCATION MAP
48 0 48 96
SCALE IN MILES
Radio Tower
PIPELINE
Water Tank
WT
BM 596
Airstrip
Ravenswood
Ritchies Pond
WEST VIRGINIA
OHIO
Mile 220
NORMAL POOL ELEV 560
PO
Sewage Disposal
Station
High Sch
Lick Run
SANDY CREEK
A
B
C
D
Creek
GREAT BEND
Wells
Well
Light
Trailer Park
Run
SCHEME LENGTH, ft
A 407
B 328
C 376
D 300
OHIO RIVER
RAVENSWOOD, W. VA.
1,000 0 1,000 2,000 3,000
SCALE IN FEET

EXHIBIT I-1

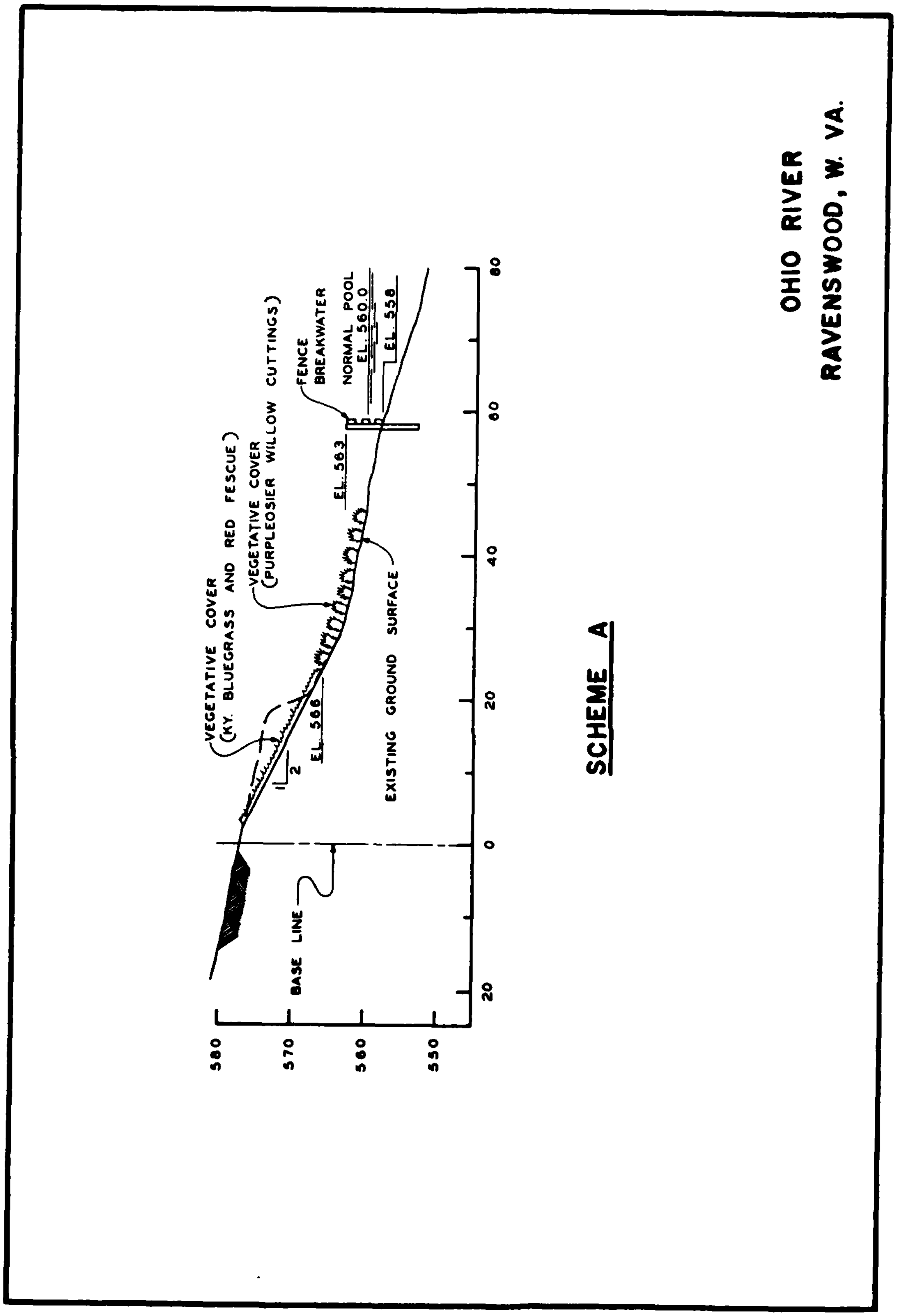
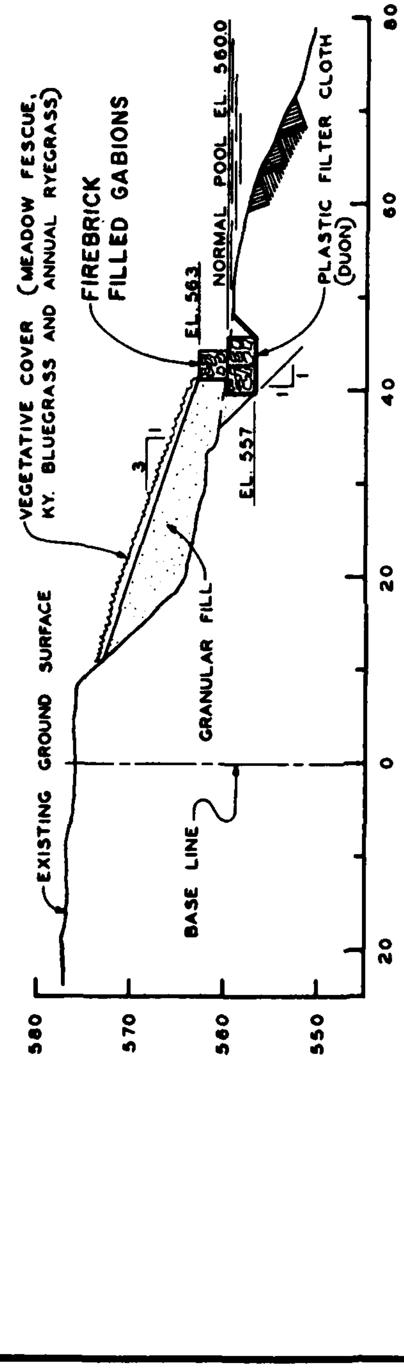

OHIO RIVER
RAVENSWOOD, W. VA.
SCHEME A
VEGETATIVE COVER (KY. BLUEGRASS AND RED FESCUE)
VEGETATIVE COVER (PURPLEOSIER WILLOW CUTTINGS)
FENCE BREAKWATER
NORMAL POOL EL. 560.0
EL. 558
EL. 563
EL. 566
1
2
EXISTING GROUND SURFACE
BASE LINE
580
570
560
550
20
0
20
40
60
80

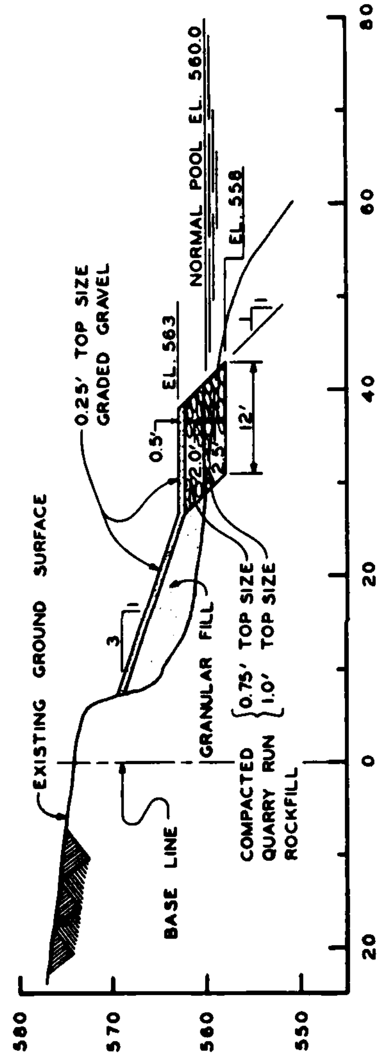
EXHIBIT I-2



SCHEME B

OHIO RIVER
RAVENSWOOD, W. VA.

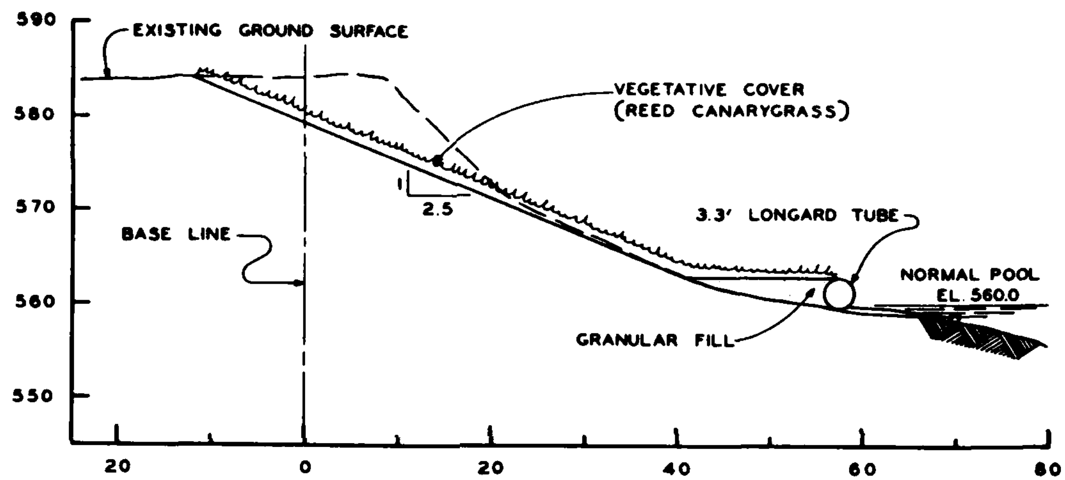
EXHIBIT I-3



SCHEME C

OHIO RIVER
RAVENSWOOD, W. VA.

EXHIBIT I-4



SCHEME D

OHIO RIVER
RAVENSWOOD, W. VA.

EXHIBIT I-5

COST SUMMARY
Ravenswood, W. Va., Demonstration Project

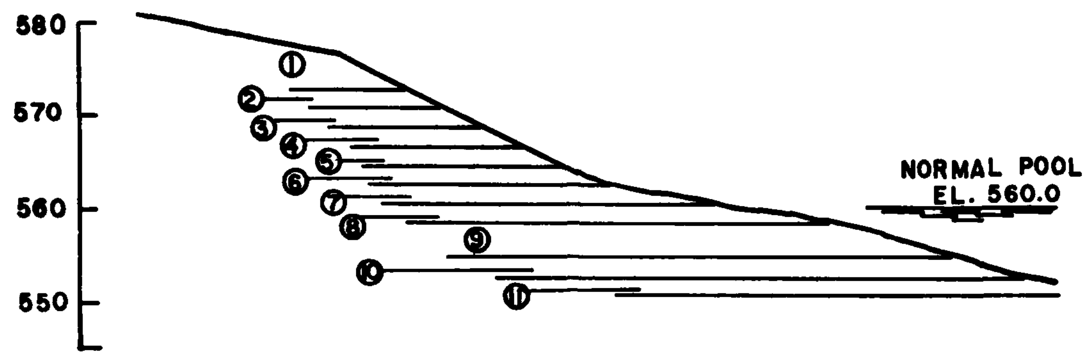
ITEM	TOTAL COST	COMMENTS
Construction	$ 136,080	
Engineering & Design	54,260	
Supervision & Administration	14,400	
Monitoring	1,000	
Reconstruction	2,000	Repairs to Longard Tube and replanting of vegetation cover
TOTAL	$ 207,740	

CONSTRUCTION COST FOR EACH TREATMENT

Type of Protection		Cost per Lineal foot	Cost per Square Foot
Scheme A:	breakwater fence	$ 73.17	$ 2.10
Scheme B:	Firebrick gabions	124.23	3.99
Scheme C:	Stone	94.49	4.01
Scheme D:	Longard Tube	100.09	2.62

These costs include all preparation of slopes and installation

EXHIBIT I-6



1. SILTY SAND, br., damp, non pl./rts., org.mat., topsoil
2. CLAYEY SILTY SAND, br., damp, sli.pl./rts.
3. SILTY SAND, br., damp, non pl./rts.
4. SILTY SAND, br., damp, non pl./rts., sa. se. fer. sta. ve. t. lay.
5. SAME AS #4/tr. cl. mst.
6. SAME AS #2/sa. se. fer. sta. ve. t. lay
7. SILTY SAND, br., wet, ve. sli. pl./rts.
8. SILTY SAND, br., wet, non pl./tr. cl. nod.
9. SANDY CLAY, gr., mst., pl.
10. SILTY SAND, br., wet, non pl./so. gr. sl. sa.
11. SANDY CLAY, gr., wet, pl./rts.

GEOTECHNICAL CROSS SECTION
RAVENSWOOD, W. VA.

EXHIBIT I-7 (SHEET 1 OF 2)

ABBREVIATIONS

a.	angle
alt.	alternat(e)(ly)(ing)
amt.	amount
ang.	angular
approx.	approximate(ly)
ar.	argillaceous
aren.	arenaceous
asp.	asphaltic
b.	bone
ba.	banded(ing)
bd.	bed(ded)(ing)
bdr.	bedrock
bf.	buff
bk.	black
bky.	blocky
bkn.	broken
bl.	blue
bou.	boulder(s)
bre.	breccia(ted)
br.	brown
c.	coarse
ca.	calcareous
carb.	carbonaceous
cav.	cavern, cavity
cbl.	cobble(y)
ch.	chert
cl.	clayey
cle.	clean
coa.	coated(ing)
comp.	compact
conc.	concretion
cong.	conglomeratic
cont.	contains
cr.	crushed
crm.	crumbly
cst.	crystal(line)
cem.	cement(ed)
di.	dirty
dia.	diameter
diag.	diagonal
dis.	disintegrated
disc.	discontinuous
diss.	disseminated
dk.	dark
dn.	dense
dmp.	damp
ext.	extremely
f.	fine
fer.	ferruginous
fis.	fissile
fil.	filled(ing)
fos.	fossil(iferous)
frac.	fracture(d)
frags.	fragment(s)(al)
fri.	friable
f.w.	free water
g.	grain(ed)
gen.	generally
gn.	green
gr.	gray
gra.	gravelly
grad.	grading(ed)
G.W.	ground water
h.	hard
ha.	high angle
hi.	high(ly)(er)
hor.	horizontal(ly)
inc.	inclusions
incr.	increasing(ly)
inla.	interlaminated
intbd.	interbedded
irr.	irregular
jt.	joint(ed)
l.	little
la.	low angle
las.	laminat(ions)(ed)
lay.	layer(s)
le.	lean
lea.	leached
len.	lense(s)
lg.	large
lt.	light
m.	moderate(ly)
ma.	many
mas.	massive(ly)
mat.	material
mic.	micaceous
min.	mineralized
mos.	mostly
mot.	mottled
mst.	moist
mtx.	matrix
n.	near
nod.	nodule(s)
num.	numerous
o.	open
occ.	occasional(ly)
occu.	occurring
org.	organic
pa.	parting(s)
part.	particle(s)
pl.	plastic
peb.	pebble(s)
pk.	pink
pkt.	pocket(s)
pit.	pit(ted)
pn.	plane(s)
po.	porous
pt.	part(ly)
pyr.	pyrite(ic)
q.	quartzitic
r.	red
ro.	rock(s)
rot.	rotten(ed)
rou.	round(ed)
rt.	root(s)(let)
s.	soft
sa.	sandy
sat.	saturated
scat.	scattered
se.	seams
sev.	severely
sevr.	several
sh.	shaly
sil.	siliceous
sl.	silty
sli.	slight(ly)
slk.	slickensided
sm.	small
so.	some
sol.	solution
sta.	stain(ed)
stf.	stiff
stks.	streak(s)
str.	stringer(s)
sty.	stylolite(ic)
t.	thin
tho.	throughout
tk.	thick
tr.	trace
v.	variably
va.	variegated
ve.	very
veg.	vegetation
ver.	vertical(ly)
vu.	vuggy
w.	water
/	with
w.c.	water content
wd.	weathered
whi.	white
x-bd.	cross bedded(ing)
y.	yellow
zo.	zone

GEOTECHNICAL CROSS SECTION

EXHIBIT I-7 (SHEET 2 OF 2)

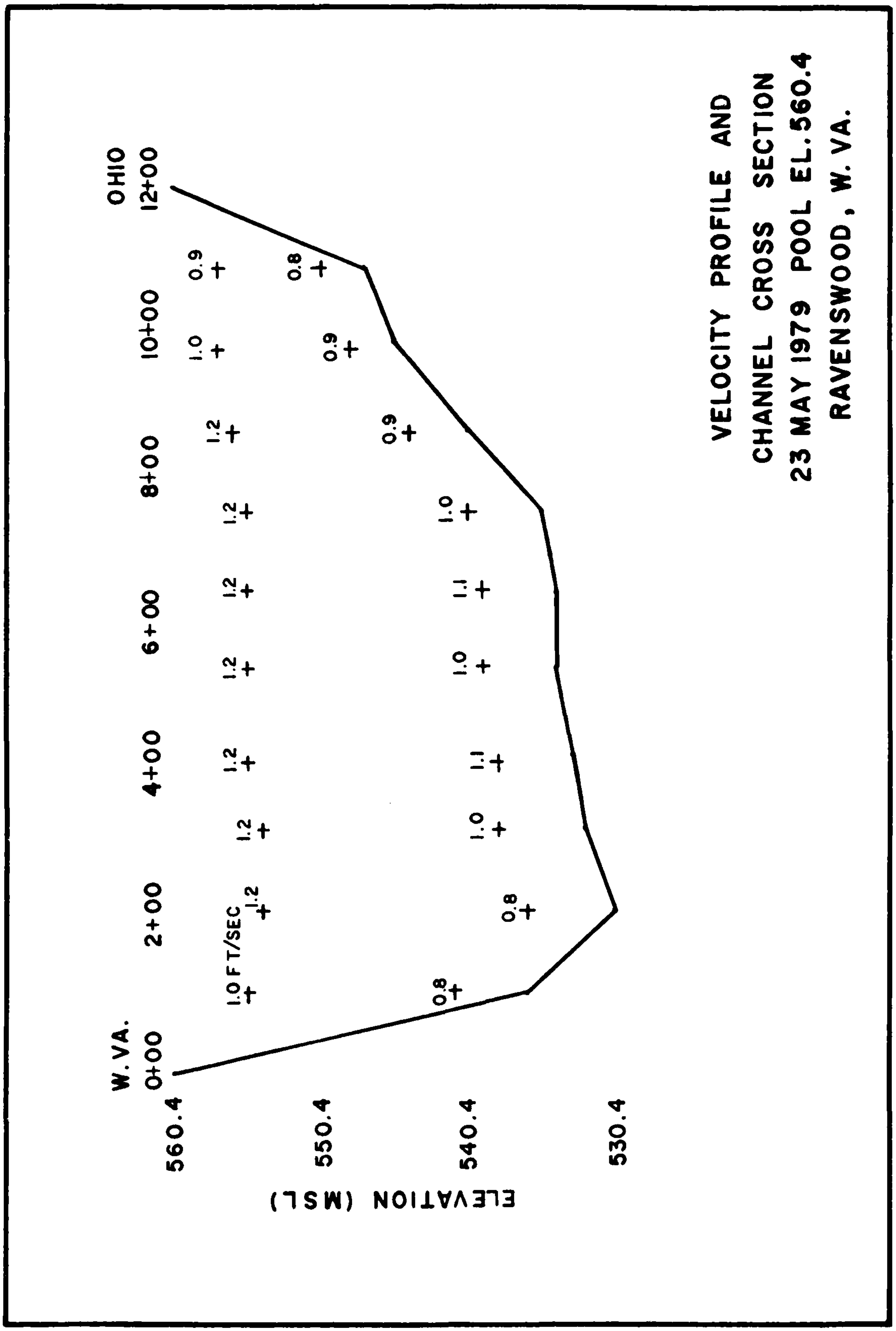
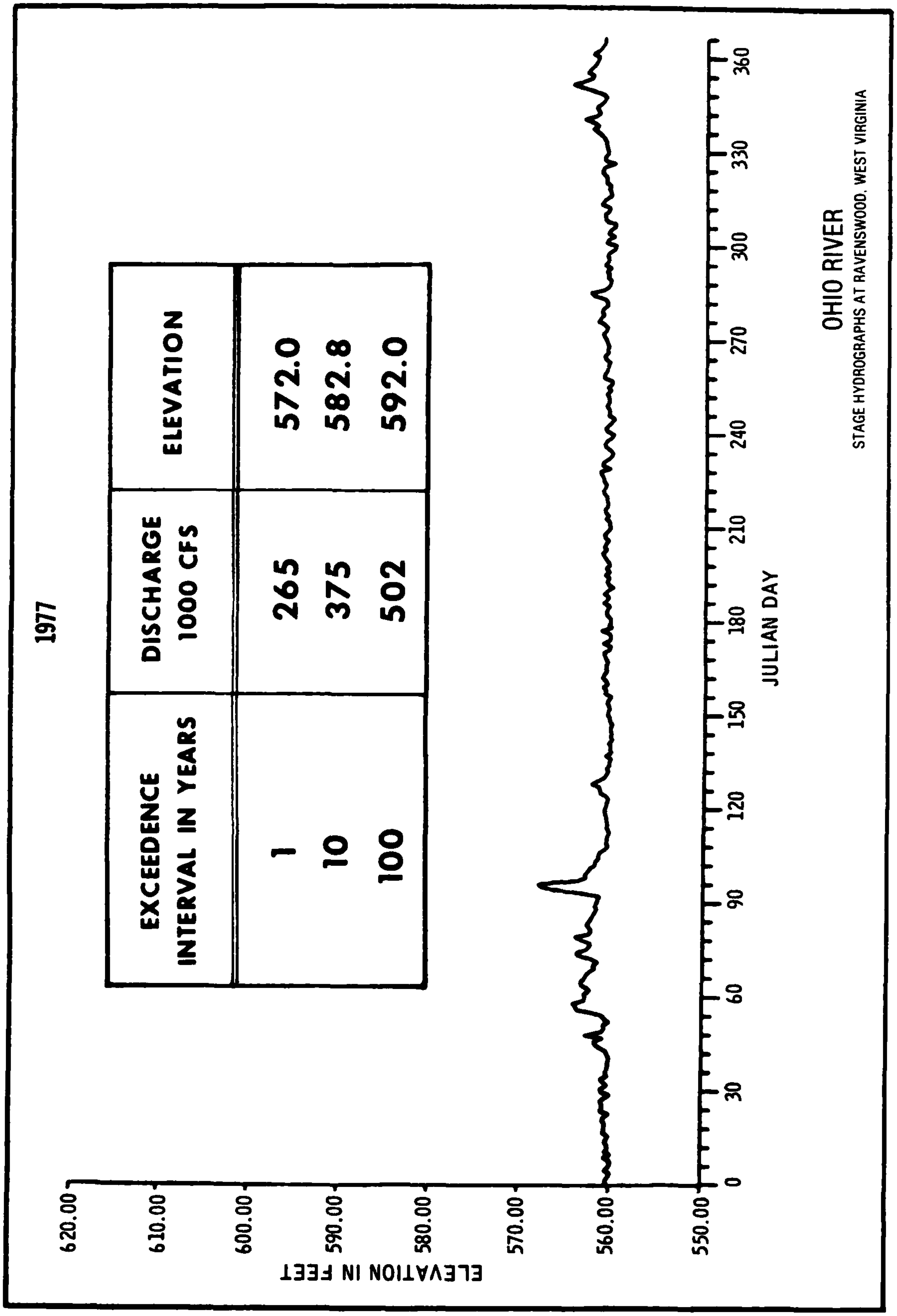

VELOCITY PROFILE AND
CHANNEL CROSS SECTION
23 MAY 1979 POOL EL. 560.4
RAVENSWOOD, W. VA.
ELEVATION (MSL)
560.4
550.4
540.4
530.4
W. VA.
OHIO
0+00
2+00
4+00
6+00
8+00
10+00
12+00
1.0 FT/SEC
1.2
1.2
1.2
1.2
1.2
1.2
1.2
1.0
0.9
0.8
1.0
1.1
1.0
1.1
1.0
0.9
0.9
0.8

EXHIBIT I-8



EXCEEDENCE INTERVAL IN YEARS	DISCHARGE 1000 CFS	ELEVATION
1	265	572.0
10	375	582.8
100	502	592.0

EXHIBIT I-9 (SHEET 1 OF 5)

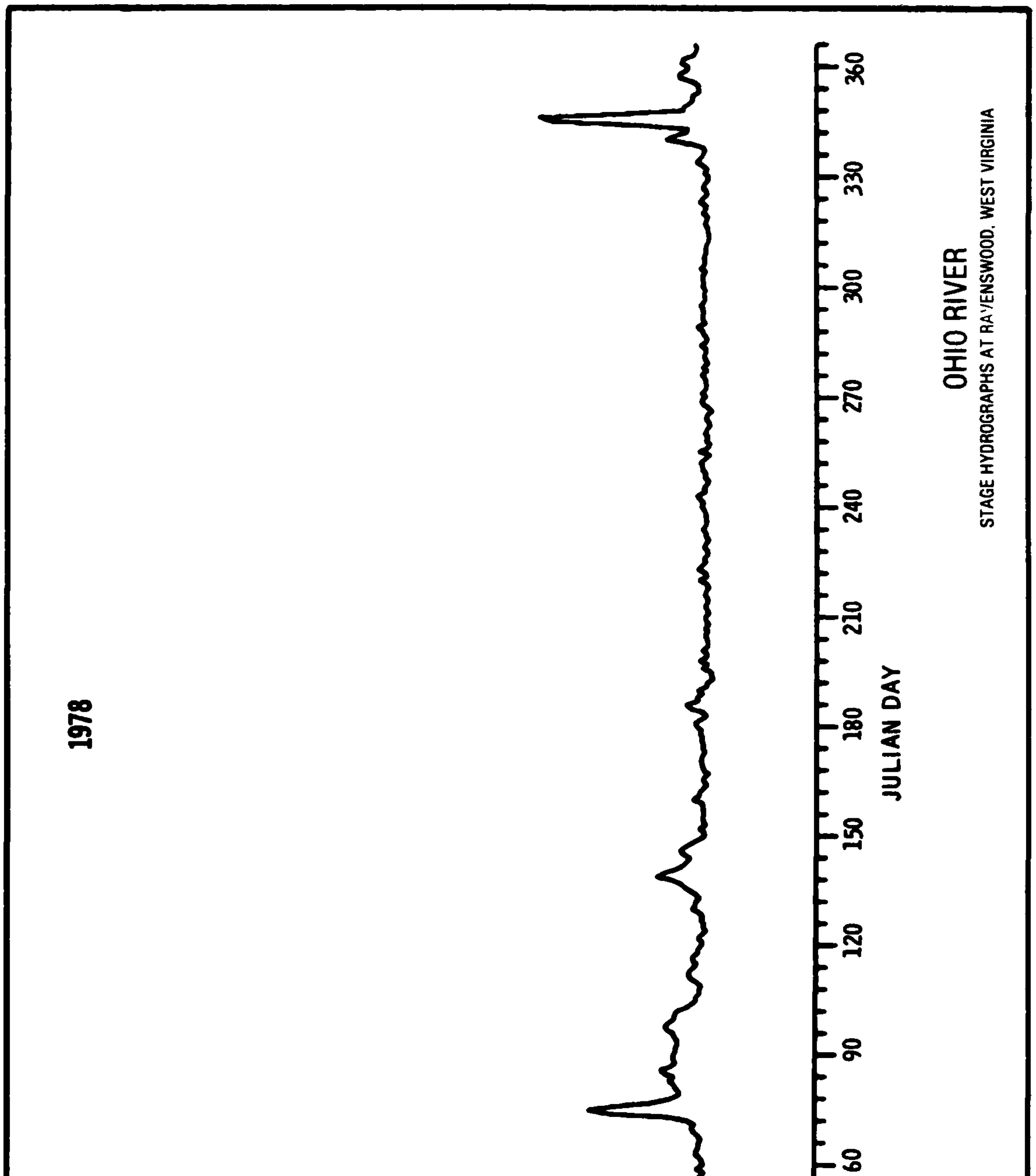


EXHIBIT I-9 (SHEET 2 OF 5)

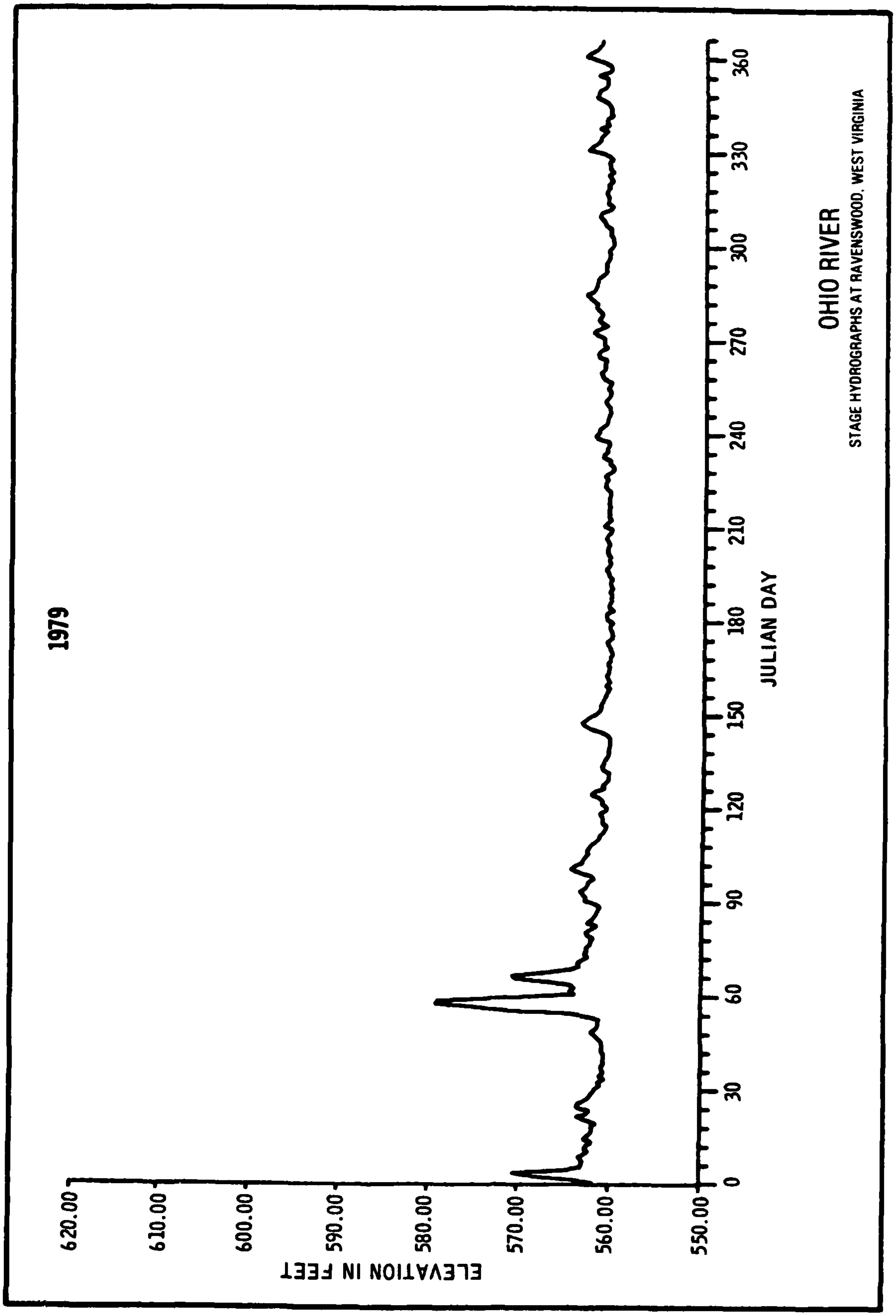


EXHIBIT I-9 (SHEET 3 OF 5)

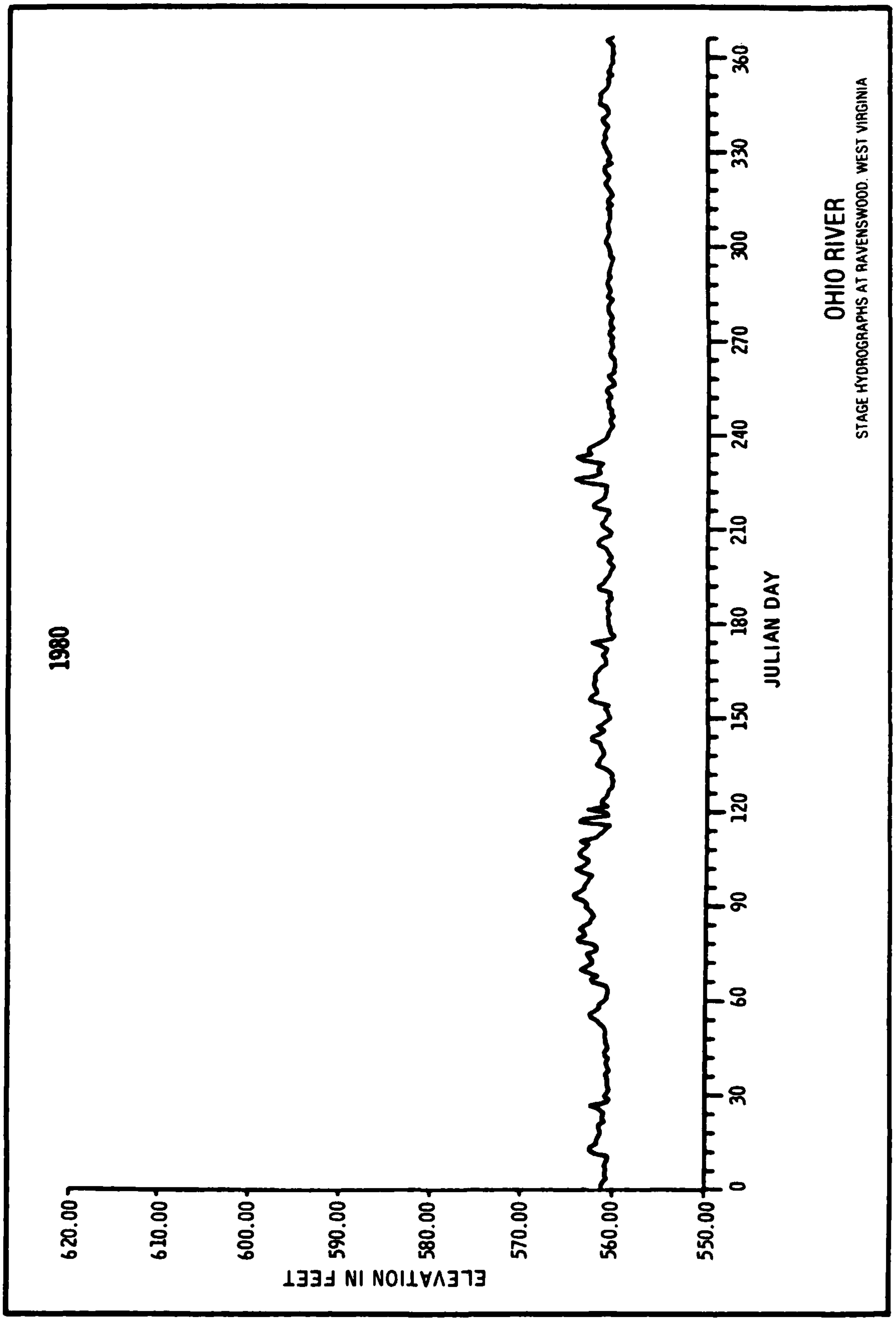


EXHIBIT I-9 (SHEET 4 OF 5)

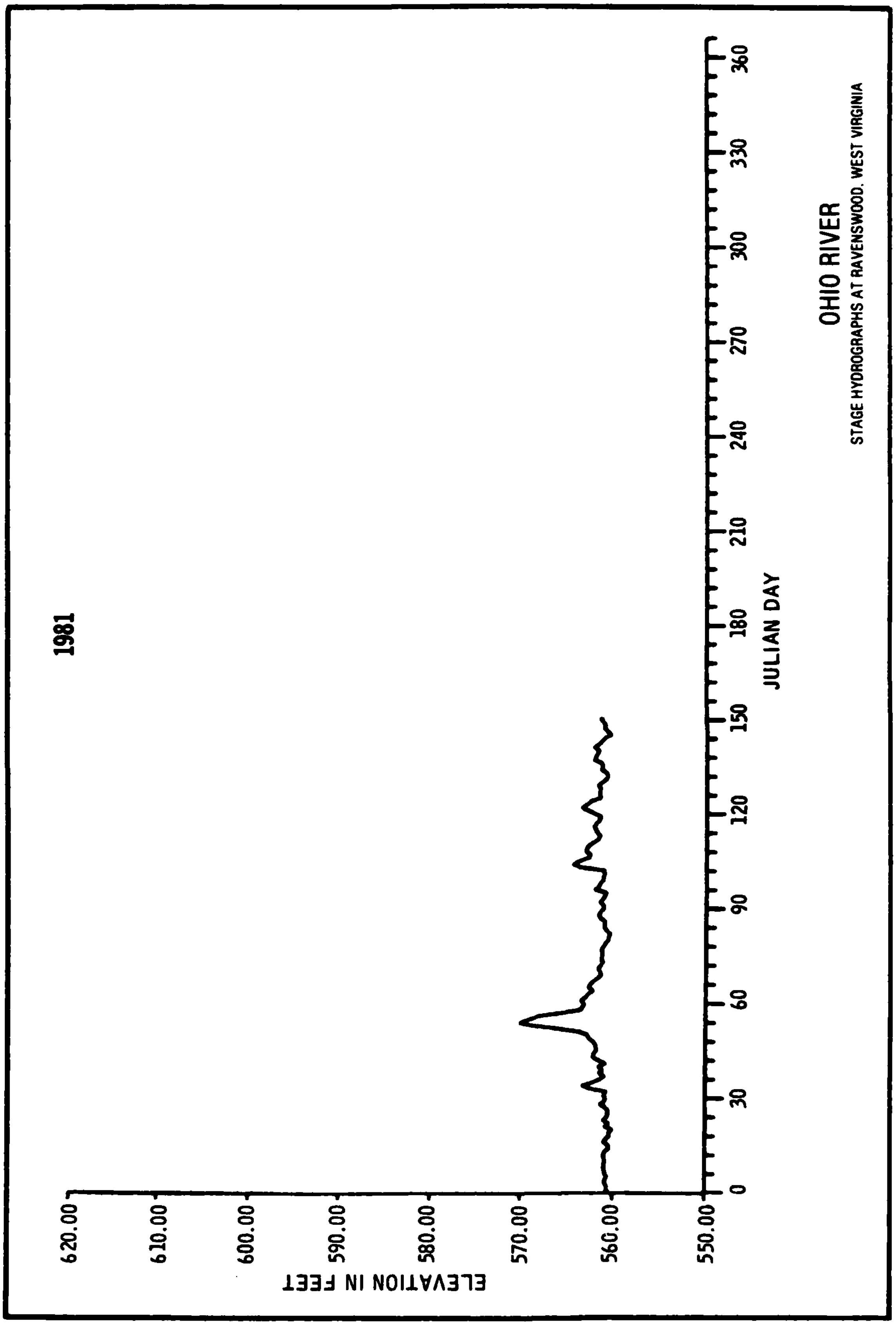


EXHIBIT I-9 (SHEET 5 OF 5)

DEMONSTRATION PROJECT
STREAMBANK EROSION CONTROL
OHIO RIVER AT RAVENSWOOD, WEST VIRGINIA
MAY 1977

Section 404 Evaluation

1. In accordance with 33 CFR 209.145 and 40 CFR 230, the following report is submitted concerning the Section 404 evaluation for the Ravenswood, West Virginia Demonstration Project.

2. Project Location and Description. The proposed demonstration project consists of four sites for streambank erosion control along an approximate 1,440 foot reach of the Ohio River in the vicinity of Ravenswood. The four installations are to be located along the left descending bank of the river between milepoints 220.56 and 220.70 below Pittsburgh, Pennsylvania. The Racine Locks and Dam is located 17.3 miles downstream of the site and maintains a normal pool elevation of 560 feet MSL. This work is being done under the auspices of Section 32 of Public Law 93-251, the "Streambank Erosion Control Evaluation and Demonstration Act of 1974." Each scheme will employ a method incorporating structural, vegetal, or a combination of erosion control measures. All four schemes will require grading, excavation, re-contouring and/or compaction or soil preparation. There will be a balance of materials and no spoil area is required. Test areas will be maintained and monitored for 3 to 5 years by the Huntington District. The plans and descriptions are contained in the enclosed Public Notice and Environmental Assessment.

3. Coordination. An agreement was made with the City of Ravenswood for non-Federal cooperation necessary for the construction and maintenance of the project. Concerned West Virginia U. S. Representatives and Senators have submitted their views in favor of the project. The Public

Notice dated September 3, 1976, was sent to the Governor of West Virginia, all concerned Senators and Representatives, appropriate Federal, State, and local agencies.

4. Objections Received from Public Notice. No objections or requests for a public meeting were received as a result of the Public Notice.

5. Comments from Federal, State and Local Agencies. Responses were received from the U. S. Environmental Protection Agency and the Bureau of Sport Fisheries and Wildlife. The EPA has no objections to the project and said the long term effect would be to improve water quality. They requested that turbibity increases be minimized during construction and that vegetated areas which are disturbed be stabilized as soon as possible. The Bureau of Sport Fisheries and Wildlife recommended that vegetation along the bank be preserved, especially the large trees and habitat in the Ravenswood Park area. Hand placement of the riprap should be done if necessary.

6. Response from District Engineer. The construction work will be planned and monitored to decrease the amount of sediment entering the river. Most larger trees will be preserved along the bank as these will help to anchor the bank soil. The planting of willow, cottonwood and grass at the various sites will replace vegetation lost in grading.

7. Probable Effects of the Proposed Project.

(a) Navigation. There would be no effects on navigation.

(b) Flood Heights and Damage Protection. There will be no effect on flood heights. Damage to the bank and adjacent roadway will probably be minor or prevented in the event of flood heights.

(c) Bank Erosion. The project should control bank erosion within the project area to different degrees depending on the method used. The success of each scheme will be judged over the next five years.

EXHIBIT I-10 (SHEET 2 OF 4)

(d) Conservation. The bank stabilization would prevent loss of valuable land and soil due to erosion. The larger trees within the work area will be preserved and prevented from being lost due to erosion under-mining.

(e) Fish and Wildlife. The area to be stabilized contains only a small amount of permanent cover for wildlife because of the periodic erosion and slumping. All of the schemes would required planting vegetative cover where practical. In cases where the bank must be cut or graded, selected trees will be saved. Granular filled areas will be planted with grass, or willows and cottonwoods. Sedimentation will be reduced and should improve the habitat for benthic and fish life along the bank.

(f) Water Quality. Water quality will be improved because of the elimination of sedimentation from the bank. The quarry run stone and gravel will not contribute any pollution into the river. Some sedimentation would result from the construction.

(g) Aesthetics. The appearance of the bank will be improved in contrast to the previously eroding bank. Permanent vegetation will be established and the appearance of the shoreline near the park will be improved to the benefit of users.

(h) Ecology. The modification of the bank would disrupt the ecology of the immediate area but a more stable relationship between animal and plant life would be established.

(i) Historic Value. The National Register of Historic Places was consulted and no sites would be affected by the project. One archeological site (46-JA 7) is located on the high terrace north of the junction of Sandy Creek and the Ohio River immediately adjacent to the area of the proposed action. It is located on State property and will not be disturbed by the proposed action.

(j) Recreation. The Ravenswood City Park adjoins one section of the project area and the proposed work will enhance the value of the

EXHIBIT I-10 (SHEET 3 OF 4)

park for users. Mature trees along the bank are in danger of falling into the river and will be protected. The fill materials next to the water will improve the footing and access for bank fishermen.

(k) Economy. The proposed work will save the City of Ravenswood and private property owners the cost of periodic attempts to stabilize the bank and repair Water Street which parallels the bank. Private residential building and public property along the shore will have their value maintained. The construction work could provide temporary employment and economic stimulus for construction services in the area.

(l) Water Supply. The water supply for the City of Ravenswood would not be affected.

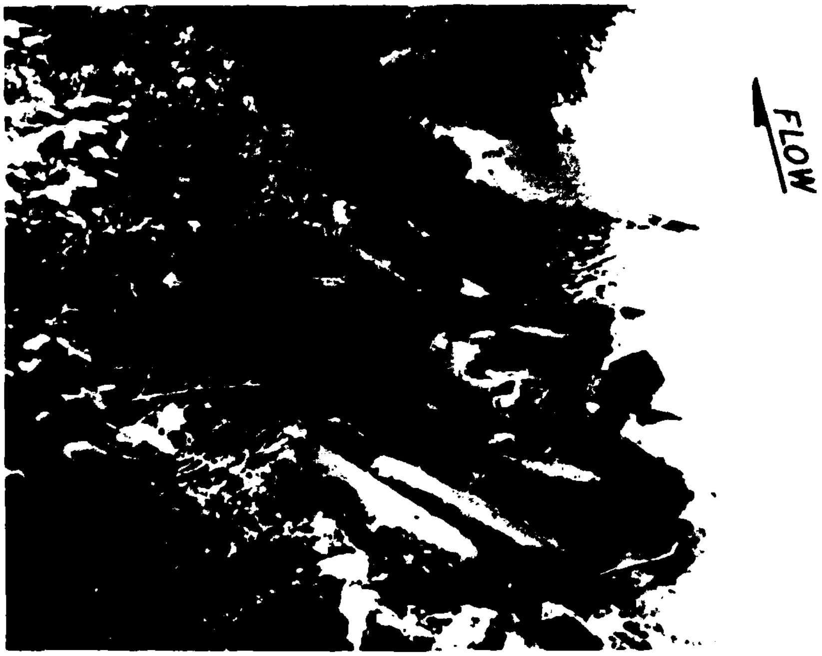
(m) Land Use Classification. Land use plans for the City and private land owners would not be adversely affected or changed. A stabilized bank would make possible a more definite plan for the use of the land along the river. Most of the work would be within the flowage easement of the Ohio River.

(n) Public Interest. Overall, the project will be a public benefit. The only adverse effects would be the temporary disruption caused by construction for about 3 months. The results of the evaluation for the effectiveness of the various schemes will enable the Corps of Engineers to provide improved bank protection in the future.

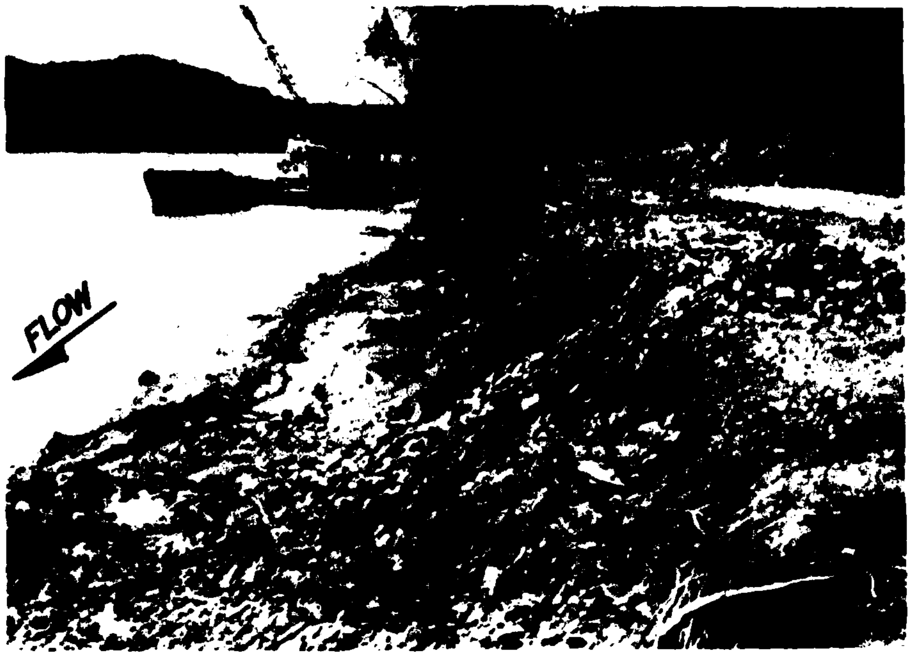
8. Conclusions. There are no public objections and the proposed project would be beneficial to the economy, social well-being, and only temporarily disruptive to the natural environment. The project would provide valuable information on effective streambank protection in the future.

9. Recommendations. It is recommended that the streambank erosion control demonstration project at Ravenswood, West Virginia, be implemented as planned, with consideration given to minimizing river turbidity and preserving trees in the project area.

EXHIBIT I-10 (SHEET 4 OF 4)



SCHEME A: LOOKING DOWNSTREAM BEFORE CONSTRUCTION



SCHEME A: LOOKING UPSTREAM DURING CONSTRUCTION

EXHIBIT II-1

SCHEME A: LOOKING DOWNSTREAM AFTER CONSTRUCTION

EXHIBIT II-2

SCHEME B: LOOKING UPSTREAM BEFORE CONSTRUCTION

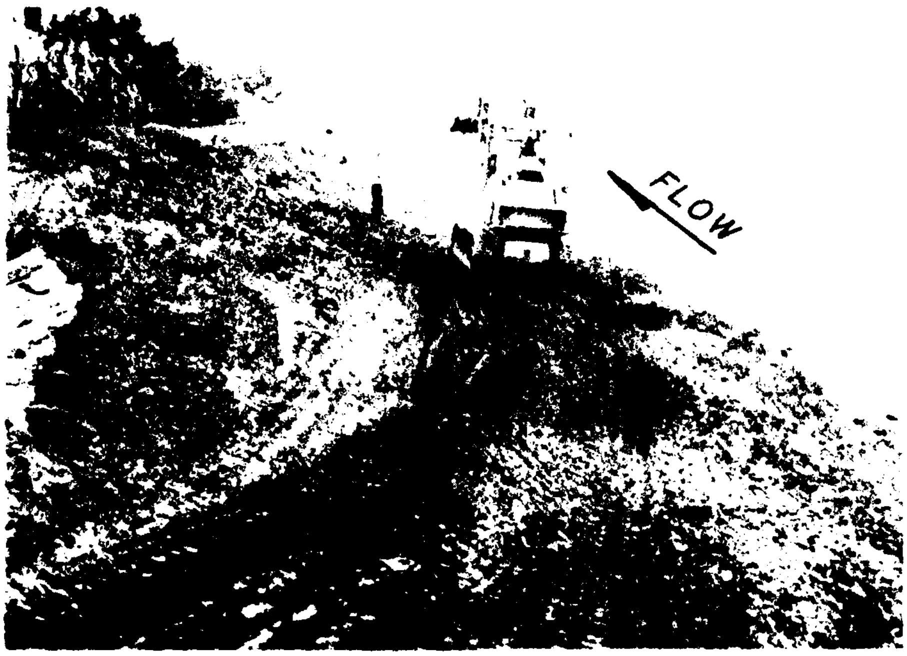
SCHEME B: LOOKING DOWNSTREAM DURING CONSTRUCTION

EXHIBIT II-3

SCHEME B: LOOKING UPSTREAM AFTER CONSTRUCTION

EXHIBIT II-4

SCHEME C: LOOKING UPSTREAM BEFORE CONSTRUCTION



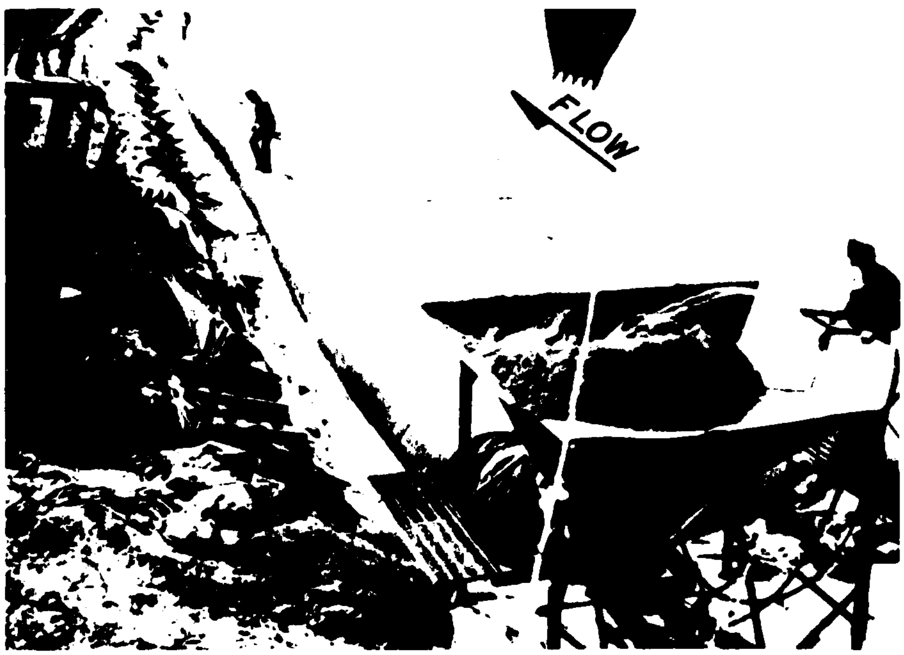
SCHEME C: LOOKING DOWNSTREAM DURING CONSTRUCTION

EXHIBIT II-5

SCHEME C: LOOKING DOWNSTREAM AFTER CONSTRUCTION

EXHIBIT II-6

SCHEME D: LOOKING DOWNSTREAM BEFORE CONSTRUCTION



SCHEME D: LOOKING DOWNSTREAM DURING CONSTRUCTION

EXHIBIT II-7

SCHEME D: LOOKING DOWNSTREAM AFTER CONSTRUCTION

EXHIBIT II-8

OHIO RIVER
SOUTH POINT, OHIO

Section 32 Program Streambank Erosion Control
Evaluation and Demonstration Act of 1974

OHIO RIVER AT SOUTH POINT, OHIO
DEMONSTRATION PROJECT PERFORMANCE REPORT

I. INTRODUCTION

A. Project Name and Location. South Point, Lawrence County, Ohio, along the right descending bank at and for a 1600 foot reach below ORM 316.7 with State Coordinate System references of N 151,264.3 and E 1,975,085.1. Exhibit No. I-1 shows the project location.

B. Authority. Streambank Erosion Control Evaluation and Demonstration Act of 1974, Section 32, P.L. 93-251.

C. Purpose and Scope. This report describes a bank failure and erosion condition, types of treatments used, and a performance evaluation of a demonstration project on the Ohio River designed and monitored by the Huntington District.

D. Problem Resume. The right bank of the Ohio River immediately upstream and opposite the confluence of the Big Sandy River and downstream of a launch ramp and approximate to a fleeting area was subject to active upper-bank failure and erosion with resultant top of slope retreat and variable encroachment on fleeting area anchorages, homesites and a launch ramp.

II. HISTORICAL DESCRIPTION

A. Stream Description, General.

1. Topography. The Ohio River at the demonstration site drains an area including Pennsylvania west of the Allegheny Mountains and portions of Kentucky, Ohio, West Virginia, New York, and Maryland. Major tributaries are the Allegheny, Monongahela, Beaver, Muskingum, Little Kanawha, Hocking, Shade, Kanawha, Guyandot, and Big Sandy Rivers. The topography of the basin is characterized by mature development of the drainage systems within the Kanawha Physiographic Section of the Appalachian Plateau Province. From its origin at Pittsburgh, the river descends 205 feet along a course of 316.7 miles to the demonstration

site. Relief at the site is approximately 800 feet from the river to the top of the surrounding valley walls. The river flows northwest at the demonstration site following a course with moderate curves of approximately 90 degrees to 110 degrees and a radii of about 6 to 7 miles. The natural stream gradient in this area is about 0.6 foot per mile. The valley floor is about one and one-half mile in width. Stream bank heights are from 15 feet to 20 feet above normal pool at the South Point Project. The South Point, Ohio, demonstration site is located along a wide alluvium terrace opposite the Big Sandy River confluence and extending upstream 6 miles on the inside of a moderate Ohio River bend.

2. Geology. The Ohio River throughout its course along the West Virginia-Ohio border has become entrenched in sedimentary strata of Pennsylvanian and older periods. These strata are made up of interbedded sandstones, siltstones, clay, shales, limestones, and coals. The bedrock valley of the Ohio River contains outwash from the Wisconsin Glacier overlain by recent alluvium. In the portion of the Ohio Valley within the project reach, the outwash is predominantly gravel, and gravelly sand overlain by sand, silty sand and clayey silt. Since the last glacial episode, the Ohio River has been cutting through and laterally into these materials with river terraces remaining as erosional remanents at various elevations in outwash and alluvium and most often by point bar accretion with the forming of a well defined flood plain. In the study area, the Ohio River is underlain by fill and outwash to depths of approximately 40 feet.

The Ohio River channel has changed location by lateral cutting and filling within the alluvium and outwash which fills the bedrock valley. The channel is, however, often bedrock controlled at its present location on one side of the Pleistocene effects-defined valley. One bank often consists of flood plain deposits and the other rock outcrop or colluvial soils which have accumulated by weathering, creep, and landslides. The colluvial soils are generally stiff silty clays with angular rock fragments and little or no layering. These soils tend to be somewhat resistant to river related erosion.

3. Locality, Development, and Occupation. The Ohio River valley in the vicinity of the demonstration site has a diverse urban and industrial land use. Over the past one hundred years most of these broad agricultural bottoms have been acquired for industrial development. Within the Greenup navigation pool, the river valley contains several small cities including Greenup, Worthington, Russell, Ashland, and Catlettsburg in Kentucky, and Ironton, Coal Grove in Ohio. Local industries include coal mining, quarries, crude oil refining, steel and chemical production, and light manufacturing. The river is paralleled by railroads and highways located approximate to both banks.

The Ohio River drainage has been an important transportation system since prehistory and has been improved for navigation beginning in 1824 when Congress provided for removal of obstructions such as bars and snags. For many years river navigation use was addressed by open channel improvements only. In addition to removal of channel obstructions, stone training dikes were constructed at various bars to restrict more frequent flows to the defined channel. The first movable dam on the Ohio River was located at Davis Island, 4.7 miles below Pittsburgh, and opened to commerce October 7, 1885. A system of locks and movable dams was eventually constructed along the entire Ohio River. In 1916, Lock and Dam 29 was put into operation 3 miles downstream of the demonstration site. These early dams incorporated a navigable pass to provide a channel for open river navigation during periods of high flow. A series of wickets, heavy timber shutters, were raised to impound water as needed to maintain a navigation pool. When not required, the wickets would lie flat at such a depth as to offer no obstruction to free navigation through the pass. Replacement of these original navigation dams with fixed, gated structures having higher lifts has been ongoing. In 1961, Greenup Locks and Dam went into full operation and Lock and Dam 29 was removed.

4. Hydrologic Characteristics. The climate of the site reach and Ohio River is continental with marked contrasts and average annual temperatures of about 54°F and an average annual precipitation of 44" rainfall. The period from 1970 through 1976 was determined to be wetter

than average. 1979 was a wet year while 1980 was average and 1981 (from 1 October 1980 to February 1981) was dryer than average. Ice occurs on all rivers and streams in the basin with the Ohio River being froze over for nearly the entire length and at this site in the winters of 1976-77 and 1977-78. Major floods affecting the Ohio River occurred in March 1913, March 1936, January 1937, March 1945, and March 1964.

5. Existing Channel Conditions. The sinuosity of the channel was described in paragraph II.A.1. The channel location and width-depth relationships have been relatively stable within historical time. Virginia Point is located on the opposite bank and immediately upstream of the South Point, Ohio, Demonstration Site.

6. Environmental Considerations. Active farming and old fields are frequently encountered within the Ohio River floodplain area. The steep hillsides adjacent to the valley floor are primarily undeveloped and consist of second growth woodlands. Within the floodplain, vegetation associated with farming and frequent site disturbance prevails. Along the river bottom land, willow, silver maple, and sycamore occur most frequently. On the hillsides and in areas of bank and slope above ordinary high water, oaks, beech, red maple, ash, black cherry and walnut exist. Nails, spikes, eye bolts, cables and physical damage from river traffic are also evident in some trees.

Fish in the project area include channel catfish, carp, smallmouth bass, white bass, pumpkinseed, bluegill, white crappie, shiners, perch, skipjacks and gizzard shad. Excellent warm-water fisheries have developed at or near the mouths of several of the tributary streams. Area wildlife resources include mourning doves, bobwhite quail, and cottontail rabbits in the approximate agricultural areas, while ruffed grouse and squirrels inhabit the uplands. Whitetailed deer are present in the adjacent uplands and also range into the valley at the site. The Ohio River also provides resting and feeding opportunities for several species of migratory waterfowl. Muskrat, raccoon, and fox are some of the fur animals in the area.

This reach of the Ohio River is exposed to various types of

pollution which tend to affect aquatic life and generally detract from the aesthetic value of the river. Organic matter, chemicals, sediment, and colloidal material contribute to degraded water quality, with seasonal variations also resulting from changes in flow and temperature.

An environmental assessment was prepared in accordance with Section 404(b) of Public Law 92-500. Impacts of construction at the site were addressed in the assessment and the effects of each bank protection scheme were considered, as were total project effects. Modifications to the riverbank during construction will cause localized and minor adverse ecological effects including degraded water quality. Construction of this project was determined to result in net beneficial environmental effects within the riverbank area.

B. Demonstration Project.

1. Hydrologic Characteristics. Channel cross sections have been determined to be generally consistent as to width-depth relationships and historical features including Virginia Point. The river channel in the immediate vicinity of the demonstration project has been subject to sand and gravel dredging. Ice formation in the project area has become significant during unusually severe winters. Ice movement is not a factor in bank erosion at the site.

2. Hydraulic Characteristics. Average velocities have, during frequently occurring excessive flow events, been determined as from 5 to 7 feet per second within the Ohio River channel. Waves have been observed and monitored under various wind and traffic conditions. Maximum wave height was approximately two feet. The minimum pool for navigation use is retained at elevation 515 by the Greenup Locks and Dam 25 miles downstream. The dam gates are raised to pass high flows, so that the influence of the dam on the river decreases with increasing flow. The influence of these navigation dams during excessive flow events is insignificant. Prior to the completion of the Greenup Locks and Dam in 1961, the Ohio River at the demonstration site was maintained at minimum pool elevation 498.5 by Lock and Dam 29.

3. Riverbank Description. The riverbank at the demonstration site is approximate to barge mooring facilities and landing and includes fill and an abandoned road and is characterized by moderate height and variable slopes. The bank is composed of fine grained alluvium deposited as point bars and during overbank event falling stages. These interbedded and interlensing sediments include silty clays overlying silty sands and sands. In the project reach of bank, dump debris and random filling are frequently encountered. A typical geotechnical cross section of the project site is referenced as Exhibit I-7.

The area immediately landward of the top of bank has low relief and is utilized for home sites.

Most failure of banks at this site occurs during flood events and as the river returns to near normal stages. A frequently encountered failure sequence in these alluvium includes internal erosion of sand and silty sand by groundwater flowing out of the riverbank, referenced as "piping" with resultant weakening of overlying soils. The bank then fails by drawdown-related slumpages as the river falls from flood stages with current related erosion of in situ soils and the failed debris.

The District has been aware of bank failure and erosion at this site since historical times and inclusive of the channelization period. Photographs submitted as Exhibit Nos. II-1 thru II-8 indicate the condition of the bank prior to construction, during construction, and after construction of the demonstration project.

III. DESIGN AND CONSTRUCTION

A. General. The South Point, Ohio, site was used to evaluate four different schemes of bank protection along a reach of rather consistent upper bank topography. Regrading of failure and erosion-defined bank topography was required.

B. Basis for Design. Treatments were intended to generally address upper bank conditions at and upslope of the normal pool land-water contact. These materials were not intended to protect against mechanisms which are most significant and occur during major storms and

floods. The structural features included a series of variations on conventional stone bank protection design utilizing economical, locally available materials. Placement of these materials was somewhat labor intensive but was included as being feasible for use by small property owners with limited financial resources. Vegetation covers included grasses.

C. Construction Details. Waste concrete, rock spoil, tire mats and granular fill were placed as indicated on Exhibit Nos. I-2 thru I-5. Treatments were completed in 1981 and included these materials:

Scheme A - Regraded upper bank protection with concrete waste and rock spoil.

Scheme B - Upper bank protected with tire mats on filter cloth-reinforced sand fill.

Scheme C - Tire mat protection of regraded upper bank.

Scheme D - Waste concrete buttress of upper bank.

D. Costs. These treatments were constructed during the period from September 1980 thru January 1981. Total cost including monies to construct was $281,500. A cost breakdown for each test section, showing cost per lineal foot and cost per square foot, is included as Exhibit No. I-6.

IV. PERFORMANCE OF PROTECTION

A. Monitoring Program. Monitoring included reach of river and site specific reconnaissance, photography, mapping, sampling, and evaluations. Piezometers were installed in June 1981 and readings are scheduled to begin in July 1981. Sequential and referenced photographs for this site are included as Exhibit No. II. Site location maps, plans, reference points, sections, profiles, and details are included as Exhibit No. I.

B. Evaluation of Protection Performance.

1. General. All treatments have most probably reduced erosive losses of bank materials. The post construction period has not been sufficient to determine performance of protection treatments.

2. Scheme A and Scheme D. The waste concrete and rock spoil protections show no displacement; however, evidence of fine losses during flood events indicate a misutilization of material selection.

3. Scheme B and Scheme C. The tire mats evidence misalignment and breaks in filter cloth joints with loss of granular fill and sand during flood events.

C. Rehabilitation. No rehabilitation work has been performed.

D. Summary of Findings. Section A, the upstream treatment section of the project, consists of regraded bank covered by filter cloth and waste rock. The upriver reach of this treatment section has been extended 100 feet by the additional placement of waste rock. This test section evidences failures and spalling, weathering, and deterioration of in place materials and a loss of finer fractions and weathering products of these siltstones and silty shales exposing filter cloth at several locations within the treatment section. Some piping and related slumpages in upper bank area approximate to these treatments is evident and treatment distress is noted both within these and the waste concrete test sections. The reinforced granular fill at Section B is distressed by the loss of materials at breaks in the filter cloth. Section B and C tire mat treatments are misaligned and evidence a loss of protective sand cover over the filter cloth. Continuing material losses are resulting in the failure of these treatment systems and will require reconstruction. Waste concrete placed at the most downriver treatment, Section D, is performing satisfactorily but with loss of finer fractions leaving large masses of waste concrete without interconnection. This treatment has been inundated by excessive flow events of 22 to 26 February 1981 and 8 to 12 June 1981. These treatments have lost protective materials; however, an overall reduction in losses of bank

alluvium has been effected. Reconstruction of some reaches utilizing waste concrete and rock is required. Upper bank seepage and related failures have continued. Sediments have not accumulated within the mat protection. Upper bank accumulations of sandy fine silts to a depth of 1/10th inch were noted. Vegetation cover at this site has been effected; however, mowing by the City of South Point, Ohio, may be detrimental.

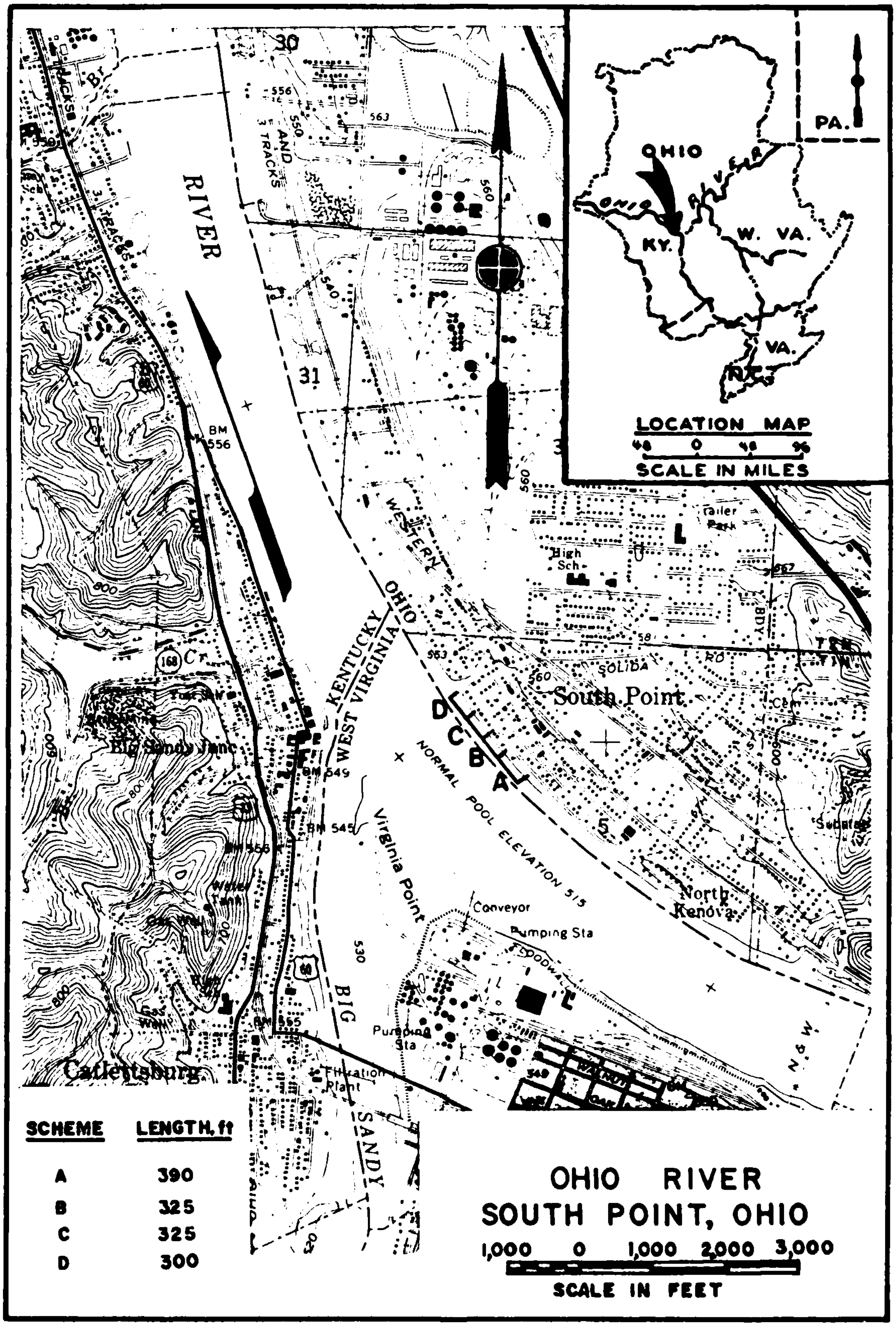
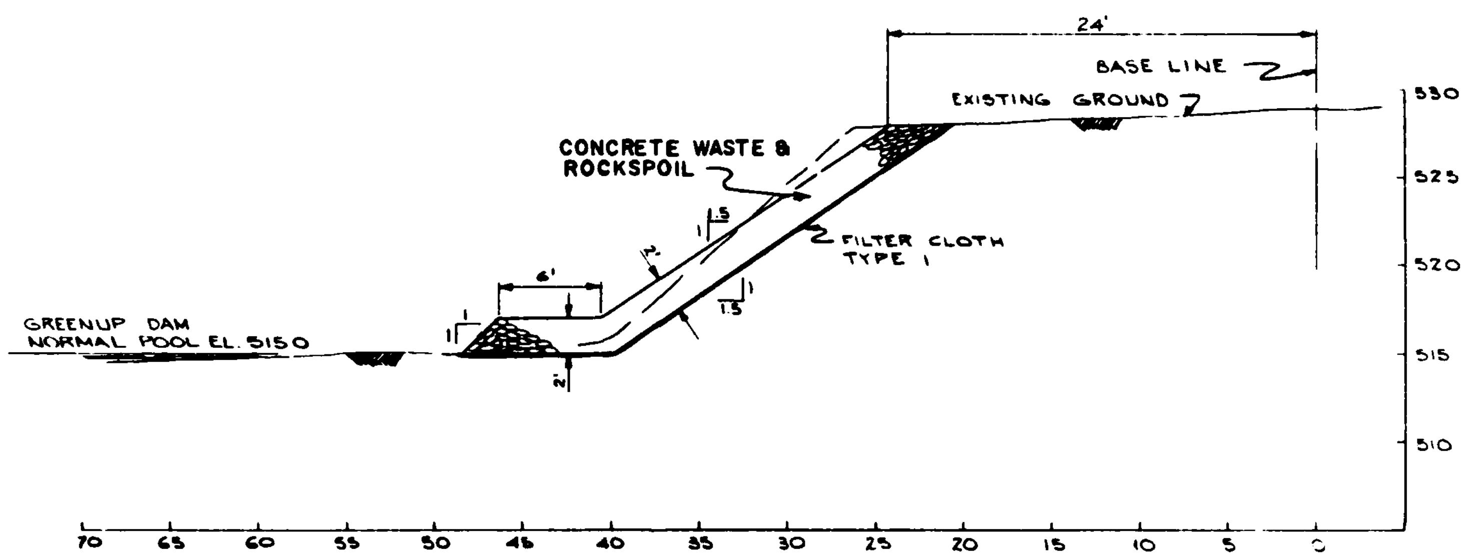

LOCATION MAP
SCALE IN MILES
OHIO
PA.
KY.
W. VA.
VA.
OHIO RIVER
RIVER
KENTUCKY
WEST VIRGINIA
South Point
North Kenova
Catlettsburg
Big Sandy Junc
Virginia Point
BIG SANDY
NORMAL POOL ELEVATION 515
Conveyor
Pumping Sta
Filtration Plant
High Sch
Trailer Park
3 TRACKS
D
C
B
A
SCHEME	LENGTH, ft
A	390
B	325
C	325
D	300
OHIO RIVER
SOUTH POINT, OHIO
1,000 0 1,000 2,000 3,000
SCALE IN FEET

EXHIBIT I-1



SCHEME A

OHIO RIVER
SOUTH POINT, OHIO

EXHIBIT I-2

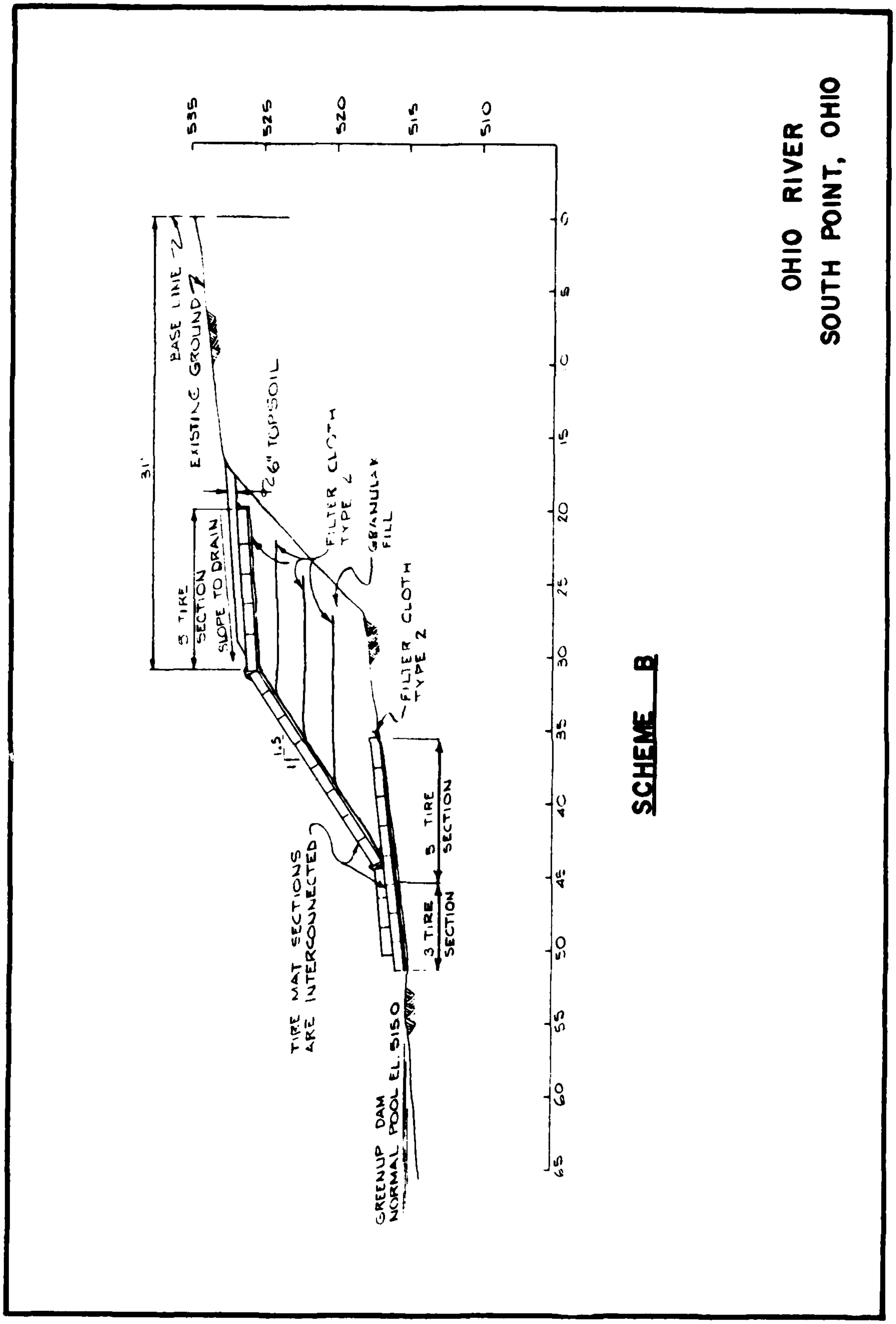

OHIO RIVER
SOUTH POINT, OHIO
SCHEME B
BASE LINE
EXISTING GROUND
6" TOPSOIL
FILTER CLOTH TYPE 4
GRANULAR FILL
FILTER CLOTH TYPE 2
5 TIRE SECTION SLOPE TO DRAIN
31'
1:1.5
TIRE MAT SECTIONS ARE INTERCONNECTED
5 TIRE SECTION
3 TIRE SECTION
GREENUP DAM NORMAL POOL EL. 515.0
535
525
520
515
510
0
5
10
15
20
25
30
35
40
45
50
55
60
65

EXHIBIT I-3

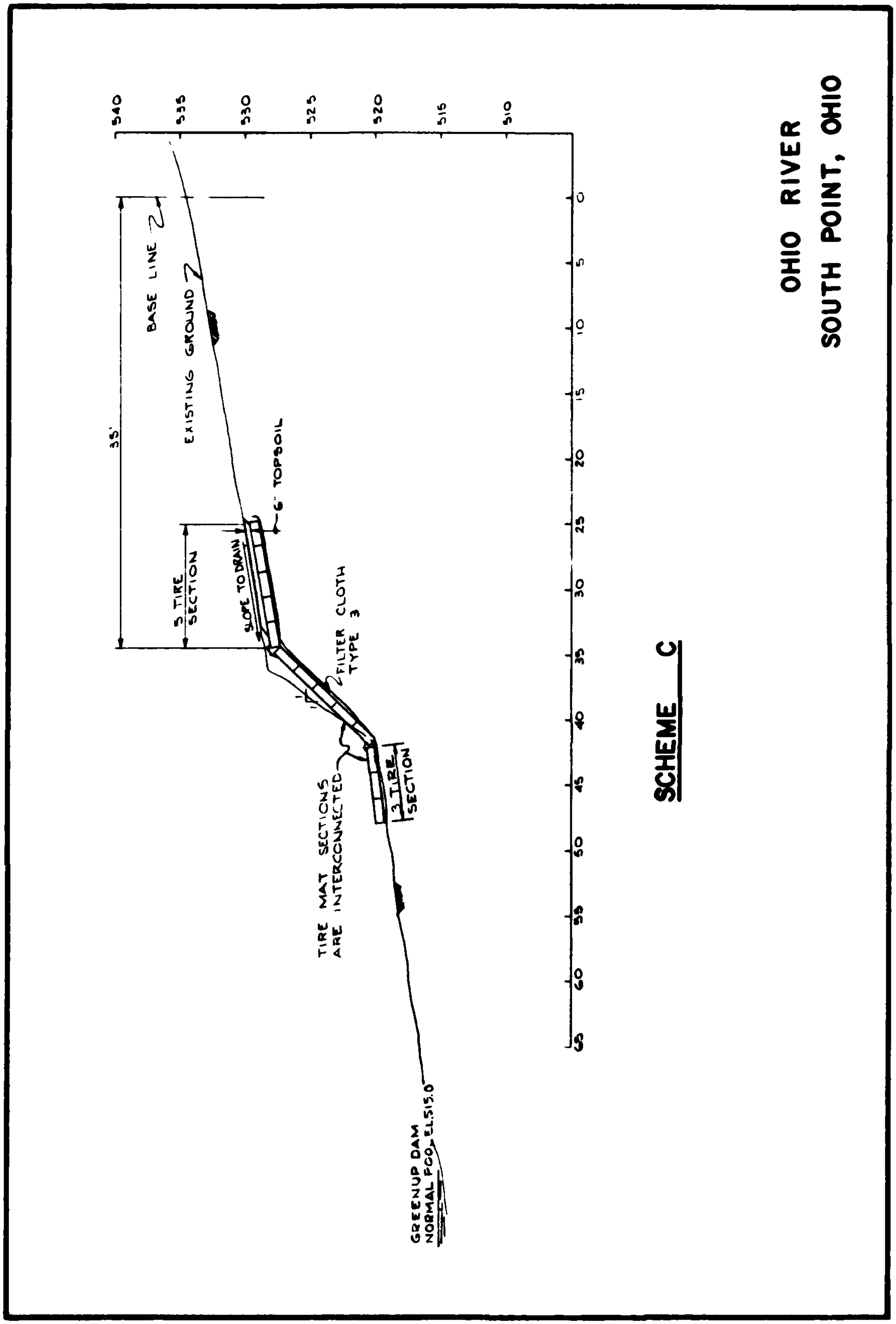

OHIO RIVER
SOUTH POINT, OHIO
SCHEME C
BASE LINE
EXISTING GROUND
35'
6" TOPSOIL
5 TIRE SECTION
SLOPE TO DRAIN
FILTER CLOTH TYPE 3
TIRE MAT SECTIONS ARE INTERCONNECTED
3 TIRE SECTION
GREENUP DAM NORMAL P.O. EL.515.0
540
535
530
525
520
515
510
0
5
10
15
20
25
30
35
40
45
50
55
60
65

EXHIBIT I-4

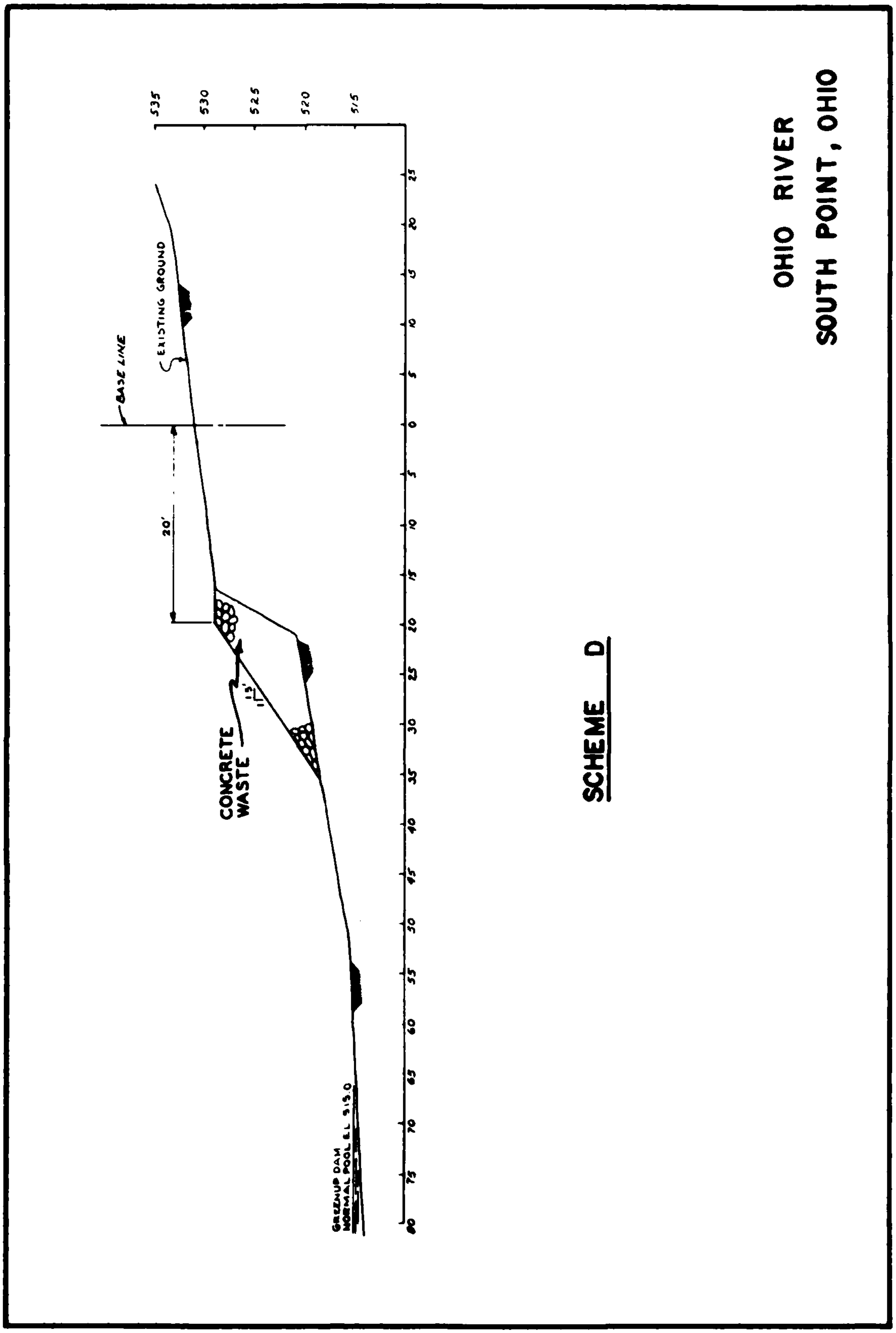

OHIO RIVER
SOUTH POINT, OHIO
SCHEME D
BASE LINE
EXISTING GROUND
20'
CONCRETE WASTE
GREENUP DAM
NORMAL POOL EL 515.0
535
530
525
520
515

EXHIBIT I-5

COST SUMMARY
South Point, Ohio, Demonstration Project

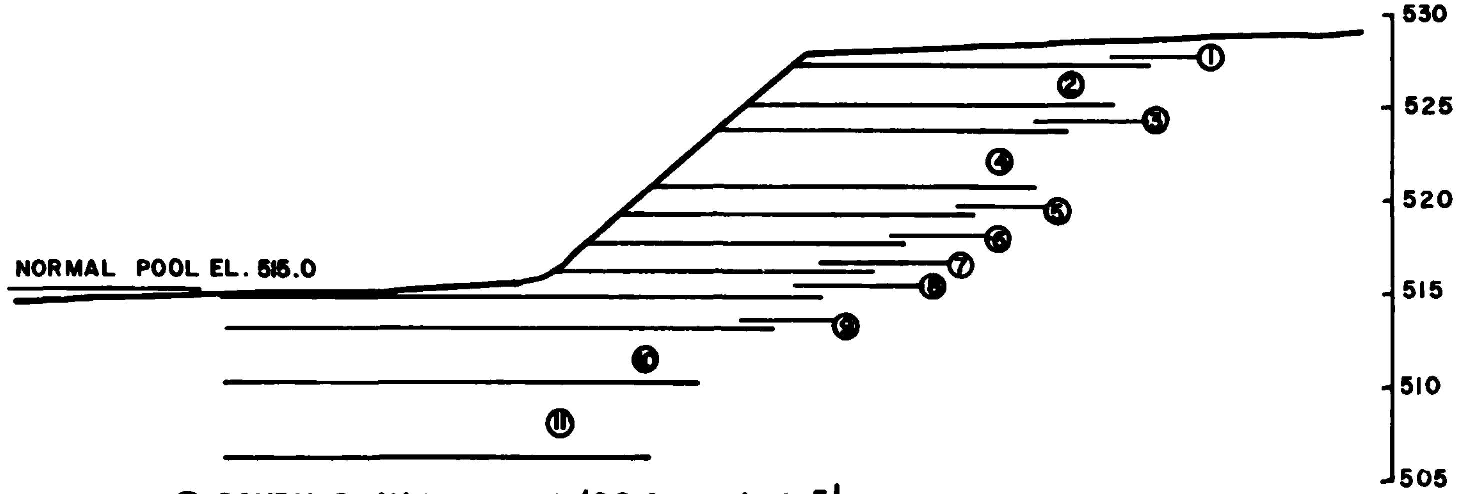
ITEM	TOTAL COST	COMMENTS
Construction	$ 191,430	
Engineering & Design	69,080	
Supervision & Administration	20,825	
Monitoring	150	
Reconstruction	0	
TOTAL	$ 281,485	

CONSTRUCTION COST FOR EACH TREATMENT

Type of Protection	Cost per Lineal foot	Cost per square foot
Scheme A: rockspoil	$ 82.66	$ 2.76
Scheme B: granular fill	275.00	6.11
Scheme C: tire mat	149.25	4.98
Scheme D: concrete waste	71.03	2.84

These cost include all preparation of slopes and installation

EXHIBIT I-6



1. SANDY CLAY, br., wet, pl./SS. frags. last .5'
2. CLAYEY SAND, br., mst., sli. pl., sa. se.
3. SILTY CLAYEY SAND, br., mst., sli. pl./sa. se. .2' tk.
4. SANDY CLAY, br., mst., pl./sa. se.
5. CLAYEY SAND, br., wet, sli. pl., org. mat./sa. se. fer. sta.
6. CLAYEY SILTY SAND, br., wet, pl., non pl./org. mat.
7. SANDY CLAY, br., wet, pl./sa. len.
8. CLAYEY SAND, br., wet, pl./sa. se.
9. SAND, gr., non pl., /sa. se., tr. cl./gr. sl. sa.
10. SILTY GRAVELLY SAND, br., wet, non pl./ro. frag.
11. SANDY GRAVEL, br., wet, tr. silt

GEOTECHNICAL CROSS SECTION
SOUTH POINT, OHIO

EXHIBIT I-7 (SHEET 1 OF 2)

ABBREVIATIONS

a.	angle
alt.	alternat(e)(ly)(ing)
amt.	amount
ang.	angular
approx.	approximate(ly)
ar.	argillaceous
aren.	arenaceous
asp.	asphaltic
b.	bone
ba.	banded(ing)
bd.	bed(ded)(ing)
bdr.	bedrock
bf.	buff
bk.	black
bky.	blocky
bkn.	broken
bl.	blue
bou.	boulder(s)
bre.	breccia(ted)
br.	brown
c.	coarse
ca.	calcareous
carb.	carbonaceous
cav.	cavern, cavity
cbl.	cobble(y)
ch.	chert
cl.	clayey
cle.	clean
coa.	coated(ing)
comp.	compact
conc.	concretion
cong.	conglomeratic
cont.	contains
cr.	crushed
crm.	crumbly
cst.	crystal(line)
cem.	cement(ed)
di.	dirty
dia.	diameter
diag.	diagonal
dis.	disintegrated
disc.	discontinuous
diss.	disseminated
dk.	dark
dn.	dense
dmp.	damp
ext.	extremely
f.	fine
fer.	ferruginous
fis.	fissile
fil.	filled(ing)
fos.	fossil(iferous)
frac.	fracture(d)
frags.	fragment(s)(al)
fri.	friable
f.w.	free water
g.	grain(ed)
gen.	generally
gn.	green
gr.	gray
gra.	gravelly
grad.	grading(ed)
G.W.	ground water
h.	hard
ha.	high angle
hi.	high(ly)(er)
hor.	horizontal(ly)
inc.	inclusions
incr.	increasing(ly)
inla.	interlaminated
intbd.	interbedded
irr.	irregular
jt.	joint(ed)
l.	little
la.	low angle
las.	laminat(ions)(ed)
lay.	layer(s)
le.	lean
lea.	leached
len.	lense(s)
lg.	large
lt.	light
m.	moderate(ly)
ma.	many
mas.	massive(ly)
mat.	material
mic.	micaceous
min.	mineralized
mos.	mostly
mot.	mottled
mst.	moist
mtx.	matrix
n.	near
nod.	nodule(s)
num.	numerous
o.	open
occ.	occasional(ly)
occu.	occurring
org.	organic
pa.	parting(s)
part.	particle(s)
pl.	plastic
peb.	pebble(s)
pk.	pink
pkt.	pocket(s)
pit.	pit(ted)
pn.	plane(s)
po.	porous
pt.	part(ly)
pyr.	pyrite(ic)
q.	quartzitic
r.	red
ro.	rock(s)
rot.	rotten(ed)
rou.	round(ed)
rt.	root(s)(let)
s.	soft
sa.	sandy
sat.	saturated
scat.	scattered
se.	seams
sev.	severely
sevr.	several
sh.	shaly
sil.	siliceous
sl.	silty
sli.	slight(ly)
slk.	slickensided
sm.	small
so.	some
sol.	solution
sta.	stain(ed)
stf.	stiff
stks.	streak(s)
str.	stringer(s)
sty.	stylolite(ic)
t.	thin
tho.	throughout
tk.	thick
tr.	trace
v.	variably
va.	variegated
ve.	very
veg.	vegetation
ver.	vertical(ly)
vu.	vuggy
w.	water
/	with
w.c.	water content
wd.	weathered
whi.	white
x-bd.	cross bedded(ing)
y.	yellow
zo.	zone

GEOTECHNICAL CROSS SECTION

EXHIBIT I-7 (SHEET 2 OF 2)

SCHEME A: LOOKING UPSTREAM BEFORE CONSTRUCTION

SCHEME A: LOOKING DOWNSTREAM DURING CONSTRUCTION

EXHIBIT II-1

SCHEME A: LOOKING DOWNSTREAM AFTER CONSTRUCTION

EXHIBIT II-2

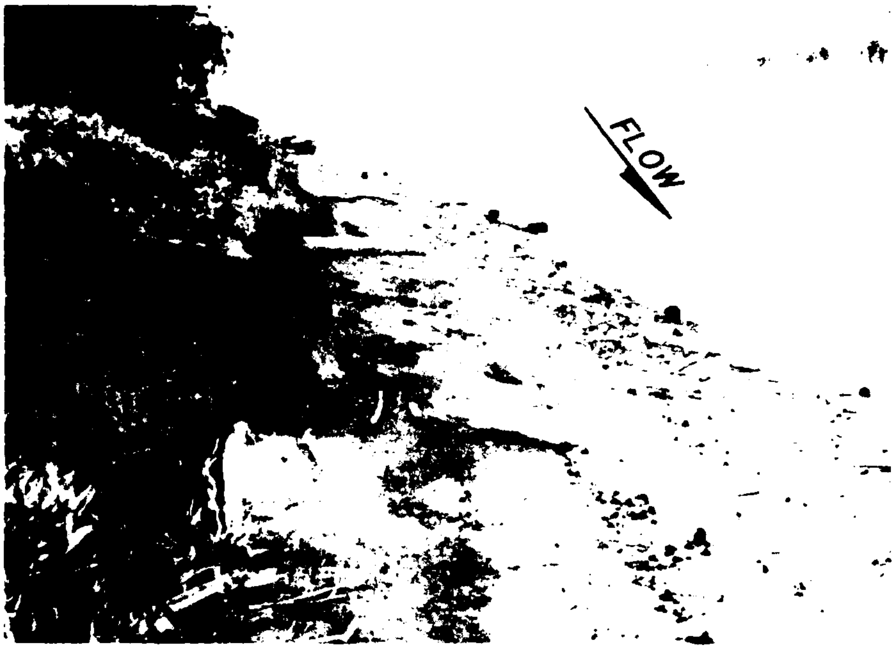
SCHEME B: LOOKING DOWNSTREAM BEFORE CONSTRUCTION

SCHEME B: LOOKING DOWNSTREAM DURING CONSTRUCTION

EXHIBIT II-3

SCHEME B: LOOKING UPSTREAM AFTER CONSTRUCTION

EXHIBIT II-4



SCHEME C: LOOKING UPSTREAM BEFORE CONSTRUCTION

SCHEME C: LOOKING UPSTREAM DURING CONSTRUCTION

EXHIBIT II-5

SCHEME C: LOOKING UPSTREAM AFTER CONSTRUCTION

EXHIBIT II-6

SCHEME D: LOOKING UPSTREAM BEFORE CONSTRUCTION

SCHEME D: LOOKING UPSTREAM DURING CONSTRUCTION

EXHIBIT II-7

SCHEME D: LOOKING DOWNSTREAM AFTER CONSTRUCTION

EXHIBIT II-8

OHIO RIVER
PORTSMOUTH, OHIO

Section 32 Program Streambank Erosion Control
Evaluation and Demonstration Act of 1974

OHIO RIVER AT PORTSMOUTH, OHIO
DEMONSTRATION PROJECT PERFORMANCE REPORT

I. INTRODUCTION

A. Project Name and Location. Portsmouth, Scioto County, Ohio, along the right descending bank at and for a 1600 foot reach below Ohio River Mile 355.1 with State Coordinate System references of Northing 268,773.7 and Easting 1,575,004.6. Exhibit No. I-1 shows the project location.

B. Authority. Streambank Erosion Control Evaluation and Demonstration Act of 1974, Section 32, P.L. 93-251.

C. Purpose and Scope. This report describes a bank failure and erosion condition, types of treatments used, and a performance evaluation of a demonstration project on the Ohio River designed and monitored by the Huntington District.

D. Problem Resume. The right bank of the Ohio River upstream of the Scioto River and the General U.S. Grant Highway Bridge and downstream of a ferry landing was subject to active failure and erosion with resultant top of slope retreat and variable encroachment on a marina, city lands including trailer park facilities and utilities and a ferry landing.

II. HISTORICAL DESCRIPTION

A. Stream Description, General.

1. Topography. The Ohio River at the demonstration site drains an area including Pennsylvania west of the Allegheny Mountains and portions of Kentucky, Ohio, West Virginia, New York, and Maryland. Major tributaries are the Allegheny, Monongahela, Beaver, Muskingum, Little Kanawha, Hocking, Shade, Kanawha, Guyandot, Big Sandy, and Little Scioto Rivers. The topography of the basin is characterized by mature development of drainage systems within the Kanawha Physiographic Section of the Appalachian Plateau Province. From its origin at Pittsburgh the river descends 220 feet along a course of 355.7 miles to the demonstration site. Relief at the site is approximately 650 feet from the river

to the top of the surrounding valley walls. The river flows southwest at the demonstration site following a course with broad curves varying from 90 degrees to 130 degrees and radii of 2 to 3 miles. The natural stream gradient in this area is about 0.6 foot per mile. The valley floor is about one mile in width. Stream bank heights are from 42 feet at Wheelersburg, Ohio, to 23 feet above normal pool at the Portsmouth Project. The Portsmouth, Ohio, demonstration site is located along a wide alluvium terrace near the Scioto River confluence and extending upstream 6 miles on the outside of a shallow bend and a straight away reach of the Ohio River.

2. Geology. The Ohio River throughout its course along the West Virginia-Ohio border has become entrenched in sedimentary strata of Pennsylvanian and older periods. These strata are made up of interbedded sandstones, siltstones, clays, shales, limestones, and coals. The bedrock valley of the Ohio River contains outwash from the Wisconsin Glacier overlain by recent alluvium. In the portion of the Ohio Valley within the project reach, the outwash is predominantly gravel, sand and gravel, and gravelly sand overlain by sand, silty sand, and clayey silt. Since the last glacial episode, the Ohio River has been cutting through and laterally into these materials with river terraces remaining as erosional remanents at various elevations in outwash and alluvium and most often by point bar accretion with the forming of a well-defined flood plain. In the study area, the Ohio River is still underlain by fill and outwash to depths of approximately 35 feet.

The Ohio River channel has changed location by lateral cutting and filling within the alluvium and outwash which fills the bedrock valley. The channel is, however, often bedrock-controlled at its location on one side of the Pleistocene effects-defined valley. One bank often consists of flood plain deposits and the other of rock outcrops or colluvial soil which have accumulated by weathering, creep, and landslides. The colluvial soils are generally stiff silty clays with angular rock fragments and little or no layering. These soils tend to be somewhat resistant to river related erosion.

3. Locality, Development, and Occupation. The Ohio River Valley in the vicinity of the demonstration site has a diverse and urban industrial land use. Over the past one hundred years most of these broad agricultural bottoms have been acquired for industrial development. Within the Meldahl navigation pool the river valley contains several small cities including Augusta, Dover, Maysville, and Vanceburg in Kentucky and Chilo, Higginsport, Manchester, Buena Vista, Portsmouth and Sciotoville in Ohio. Local industries include coal mining, quarries, steel and chemical production, electric power generation, and a variety of light manufacturing. The river is paralleled by railroads and highways located approximate to both banks.

The Ohio River drainage has been an important transportation system since prehistory and has been improved for navigation beginning in 1824 when Congress provided for removal of obstructions such as bars and snags. For many years river navigation use was addressed by open channel improvements only. In addition to removal of channel obstructions, stone training dikes were constructed at various bars to restrict more frequent flows to the defined channel. The first movable dam on the Ohio River was located at Davis Island, 4.7 miles below Pittsburgh, and opened to commerce October 7, 1885. A system of locks and movable dams was eventually constructed along the entire Ohio River. In 1919, Lock and Dam 31 was put into operation 3 miles downstream of the demonstration site. These early dams incorporated a navigable pass to provide a channel for open river navigation during periods of high flow. A series of wickets, heavy timber shutters, were raised to impound water as needed to maintain a navigation pool. When not required, the wickets would lie flat at such a depth as to offer no obstruction to free navigation through the pass. Replacement of these original navigation dams with fixed, gated structures having higher lifts has been ongoing. In 1964, Meldahl Locks and Dam went into full operation and Lock and Dam 31 was removed.

4. Hydrologic Characteristics. The climate of the site reach and Ohio River is continental with marked contrasts and average annual

temperatures of about 54°F and an average annual precipitation of 44" rainfall. The period from 1970 through 1976 was determined to be wetter than average. 1979 was a wet year while 1980 was average and 1981 (from 1 October 1980 to February 1981) was dryer than average. Ice occurs on all rivers and streams in the basin with the Ohio River being froze over for nearly the entire length and at this site in the winters of 1976-77 and 1977-78. Major floods affecting the Ohio River occurred in March 1913, March 1936, January 1937, March 1945, and March 1964.

5. Existing Channel Conditions. The sinuosity of the channel was described in paragraph II.A.1. The channel location and width-depth relationships have been relatively stable within historical time. A velocity profile and channel cross section is included as Exhibit I-8.

6. Environmental Considerations. Active farming and old fields are frequently encountered within the Ohio River floodplain area. The steep hillsides adjacent to the valley floor are primarily undeveloped and consist of second growth woodlands. Within the floodplain, vegetation associated with farming and frequent site disturbance prevails. Along the river bottom land, silver maple and willow occur more frequently. On the hillsides and in areas of bank and slope above ordinary high water, oaks, beech, red maple, ash, black cherry and walnut exist. Nails, spikes, eye bolts, cables and physical damage from river traffic are also evident in many specimens.

Fish in the project area include channel catfish, carp, spotted bass, largemouth bass, smallmouth bass, white bass, pumpkinseed, bluegill, white crappie, shiners, perch, skipjacks, gizzard shad and golden redhorse. Excellent warm-water fisheries have developed at or near the mouths of several tributary streams. Area wildlife resources include mourning doves, bobwhite quail, and cottontail rabbits in the approximate agricultural areas, while ruffed grouse and squirrels inhabit the uplands. Whitetailed deer are present in the adjacent uplands and also range into the valley. The Ohio River also provides resting and feeding opportunities for several species of migratory waterfowl. Muskrat, raccoon and fox are some of the fur animals in the area.

This reach of the river, as with the entire Ohio in general, is exposed to various types of pollution which tend to affect aquatic life and generally detract from the aesthetic value of the river. Organic matter, chemicals, sediment, and colloidal material contribute to relatively poor water quality, with seasonal variations also resulting from changes in flow and temperature.

An environmental assessment was prepared in accordance with Section 404(b) of Public Law 92-500. Impacts of construction at the site were addressed in the assessment and the effects of each bank protection scheme were considered, as were total project effects. Modifications to the riverbank during construction will cause localized and minor adverse ecological effects including degraded water quality. Construction of this project was determined to result in net beneficial environmental effects within the riverbank area.

B. Demonstration Project.

1. Hydrologic Characteristics. Channel cross sections have been determined to be generally consistent as to width-depth relationships and prehistorical features including a low water ford. The river channel in the immediate vicinity of the demonstration project has not been subject to recent sand and gravel dredging. Ice formation in the project area becomes significant only during unusually severe winters. Ice movement is not a factor in bank erosion at the site.

2. Hydraulic Characteristics. Average velocities have been monitored during frequently occurring excessive flow events and determined as 5 to 7 feet per second within the Ohio River channel. Waves have been observed and monitored under various wind and traffic conditions. Maximum wave height was approximately two feet. The minimum pool for navigation use is retained at elevation 485 by the Meldahl Locks and Dam 80 miles downstream. The dam gates are raised to pass high flows, so that the influence of the dam on the river decreases with increasing flow. The influence of these navigation dams during excessive flow

events is insignificant. Prior to the completion of the Meldahl Locks and Dam in 1964 the Ohio River at the demonstration site was maintained at minimum pool elevation 483 by Lock and Dam 31. The stage hydrographs for this project site are referenced as Exhibit I-9.

3. Riverbank Description. The riverbank at the demonstration site is approximate to a marina and ferry landing and includes extensive fill and is characterized by moderate height and variable slopes. The bank is composed of fine grained alluvium deposited as point bars and during overbank event falling stages. These interbedded and interlensing sediments include silty clays, overlying silty sands and sands. In the project reach of bank dump debris and random filling are frequently encountered. A typical geotechnical cross section of the project site is referenced as Exhibit I-7.

The area immediately landward of the top of bank has low relief and is utilized as a park. Distance to an adjacent road is from 100 to 200 feet.

Most failure of banks at this site occurs during flood events and as the river returns to near normal stages. A frequently encountered failure sequence in these alluvium includes internal erosion of sand and silty sand by groundwater flowing out of the riverbank, referenced as "piping" with resultant weakening of overlying soils. The bank then fails by drawdown-related slumpages and slabbing as the river falls from flood stages with current-related erosion of in situ soils and the failed debris.

The District has been aware of bank failure and erosion at this site since historical times and inclusive of the channelization period. Photographs submitted as Exhibit Nos. II-1 thru II-8 indicate the condition of the bank prior to construction, during construction, and after construction of the demonstration project.

III. DESIGN AND CONSTRUCTION

A. General. The Portsmouth, Ohio, site was used to evaluate four different schemes of bank protection along a reach of rather consistent upper bank topography. Regrading of failure and erosion-defined bank topography was required.

B. Basis for Design. Treatments were intended to generally address upper bank conditions at and upslope of the normal pool land-water contact. These materials were not intended to protect against mechanisms which are most significant and occur during major storms and floods. The structural features includes a series of variations on conventional stone bank protection design utilizing economical, locally available materials. Placement of these materials was somewhat labor intensive but were included as being feasible for use by small property owners with limited financial resources. Vegetation covers included grasses and purpleosier willow cutting.

C. Construction Details. Soil stabilization mat, filter cloth, and granular fill were placed as indicated on Exhibit Nos. I-2 thru I-5. Treatments were completed in 1977 and included the following materials:

Scheme A - Lower reach of upper bank protected with waste rock from a laboratory table manufacturer.

Scheme B - Upper bank toe protection using 18" top size quarry run stone.

Scheme C - Upper bank toe protection using 12" top size quarry run stone.

Scheme D - Steel furnance slag placed at toe of the upper bank.

D. Costs. These treatments were constructed during the period from October 1976 thru January 1977. Total cost including monies to construct was $251,000. A cost summary for each test section, showing cost per linear feet and cost per square foot, is included as Exhibit No. I-6.

IV. PERFORMANCE OF PROTECTION

A. Monitoring Programs. Monitoring included reach of river and site specific reconnaissance, photography, mapping, sampling, and evaluations. Piezometers were installed in June 1981. General site reconnaissance and photography were obtained, post-construction cross-sections determined in the field at completed treatments and velocity measurements obtained during excessive flows in April 1977. Sequential and referenced photographs for this site are included as Exhibit No. II. Site location maps, plans, reference points, sections, profiles, and details are included as Exhibit No. I.

B. Evaluation of Protection Performance.

1. General. All treatments have reduced erosive losses of bank materials. At bank erosion treatments failure conditions were observed to occur above the protections and in upper bank areas. Frequently encountered failure conditions in these alluvium materials have been referenced. Additionally, bank failure and soil removal mechanisms considered in the development of design concepts for treatment alternatives which are not generally significant are: wind induced and navigation-generated waves; and weather conditions (rainfall impact and runoff, and freeze and thaw cycles).

2. Scheme A and Scheme D. The waste rock and the slag show deterioration and limited downslope movements. Lower slope protection remain largely intact, however, upper bank piped openings and drawdown-related scarps of limited area extent have occurred during the post-construction period.

3. Scheme B and Scheme C. Reaches of the quarry run rock treatments have failed during storm and flood events and as a result of seasonally persistent seepages. The upper bank, which is largely dump debris, has continued to erode most often by piping and overland flows.

C. Rehabilitation. Rehabilitation at Portsmouth, Ohio, was completed during the spring of 1979 and included regrading of slopes oversteepened

by piping-related removal of silts and fine sands, and by rapid drawdown failures. Sandstone waste from a local quarry was then placed on filter cloth and revegetation effected.

D. Summary of Findings. Bank treatments evidence distress as do upper bank areas by piping, flood related removal of soils and protection materials. Additionally, these materials have been subject to deterioration from weathering processes. However, these characteristics were defined by ORDL testing and considered by the designer in sizing these materials and specifying sufficient sections. The waste rock materials in Treatment A indicate spalling and losses. Within Section B and C the quarry-run rock has experienced deterioration. Loss of material from behind the stone protection by seepage through damaged filter cloth has resulted in over-steepened topography, particularly in upper bank areas, and these conditions required rehabilitation. Additionally, current velocity-related erosion has occurred approximate to large silver maples in the upper slope areas and at other irregularities within the bank topography. Section D utilized slag protection which has experienced spalling and weathering and removal of resulted fines. Loss of protection materials has not been significant in these reaches and no reconstruction is presently required. Piping is evident in upper bank areas and at breaks in filter cloth and at locations where initial revegetation efforts were damaged by high-water events during the initial construction period. Losses of bank materials by failure and erosion processes has been reduced at this site by these treatments with willow and sycamores becoming established approximate to normal pool elevations.

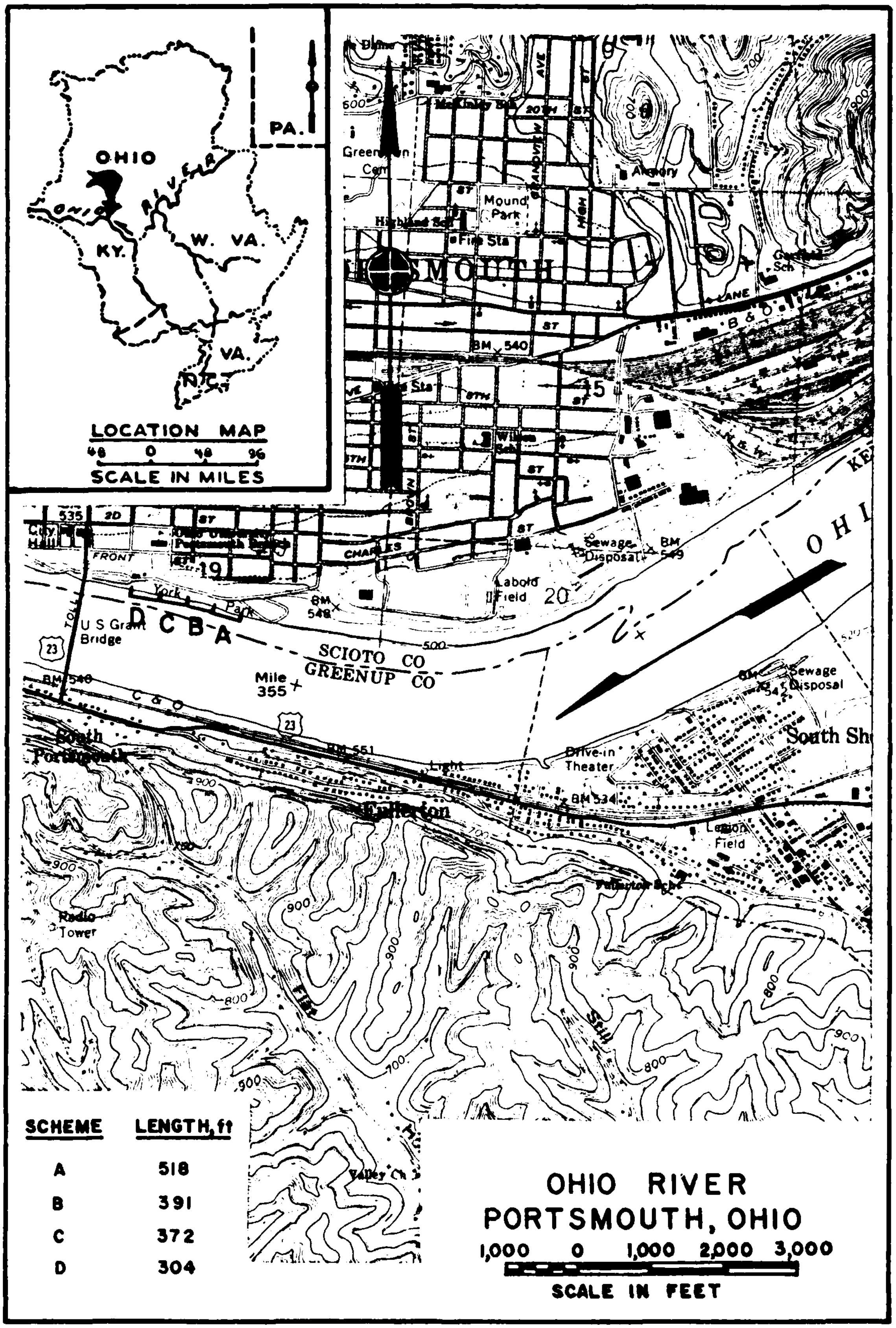

OHIO
PA.
KY.
W. VA.
VA.
N.C.
OHIO RIVER
LOCATION MAP
48 0 48 96
SCALE IN MILES
Mound Park
Fire Sta
Highland Sch
Armory
City Hall
FRONT
York Park
D C B A
U S Grant Bridge
SCIOTO CO
GREENUP CO
Mile 355
BM 540
BM 548
BM 549
BM 551
BM 534
C & O
B & O
Sewage Disposal
Laboid Field
Drive-in Theater
South Portsmouth
South Sh
Fullerton
Legion Field
Radio Tower
Valley Ch
OHIO
SCHEME LENGTH, ft
A 518
B 391
C 372
D 304
OHIO RIVER
PORTSMOUTH, OHIO
1,000 0 1,000 2,000 3,000
SCALE IN FEET

EXHIBIT I-1

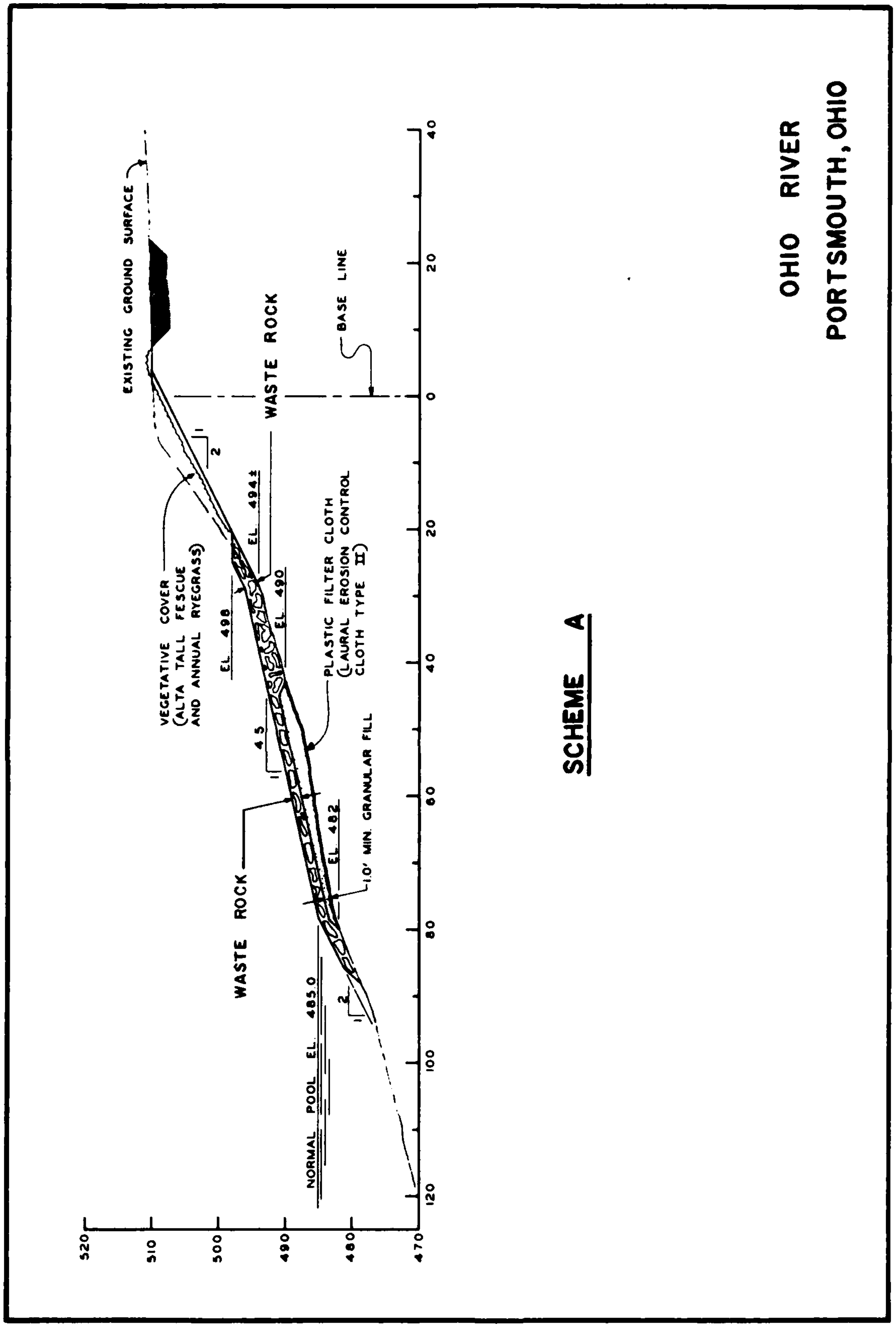

OHIO RIVER
PORTSMOUTH, OHIO
SCHEME A
EXISTING GROUND SURFACE
WASTE ROCK
BASE LINE
VEGETATIVE COVER
(ALTA TALL FESCUE
AND ANNUAL RYEGRASS)
EL 494±
EL 498
EL 490
PLASTIC FILTER CLOTH
(LAURAL EROSION CONTROL
CLOTH TYPE II)
4.5
1
2
1.0' MIN. GRANULAR FILL
EL 482
WASTE ROCK
NORMAL POOL EL 485.0
520
510
500
490
480
470
40
20
0
20
40
60
80
100
120

EXHIBIT I-2

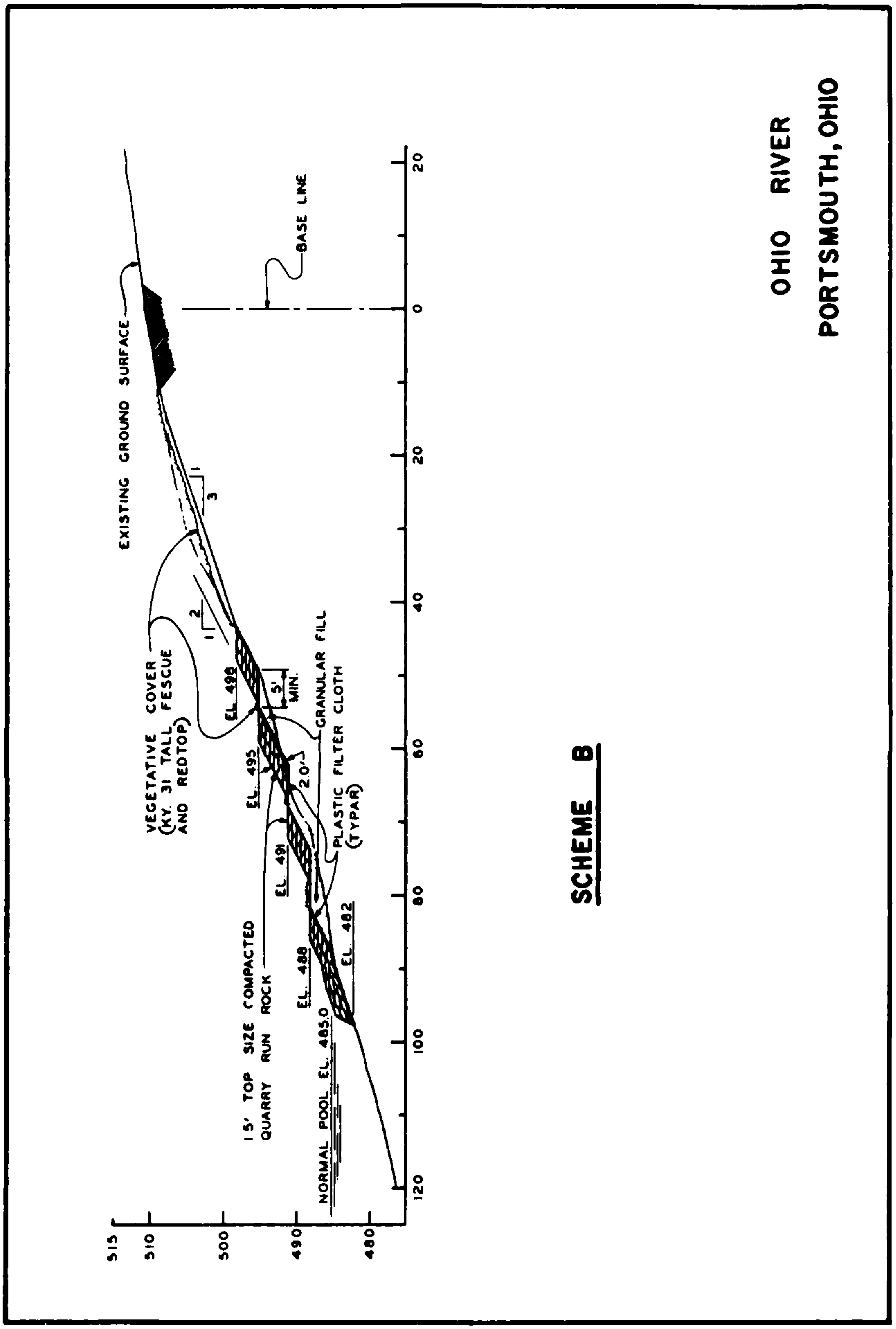

OHIO RIVER
PORTSMOUTH, OHIO
SCHEME B
EXISTING GROUND SURFACE
BASE LINE
VEGETATIVE COVER (KY. 31 TALL FESCUE AND REDTOP)
GRANULAR FILL
PLASTIC FILTER CLOTH (TYPAR)
5' MIN.
2.0'
EL. 498
EL. 495
EL. 491
EL. 488
EL. 482
1 5' TOP SIZE COMPACTED QUARRY RUN ROCK
NORMAL POOL EL. 485.0
1
3
2
1
515
510
500
490
480
20
0
20
40
60
80
100
120

EXHIBIT I-3

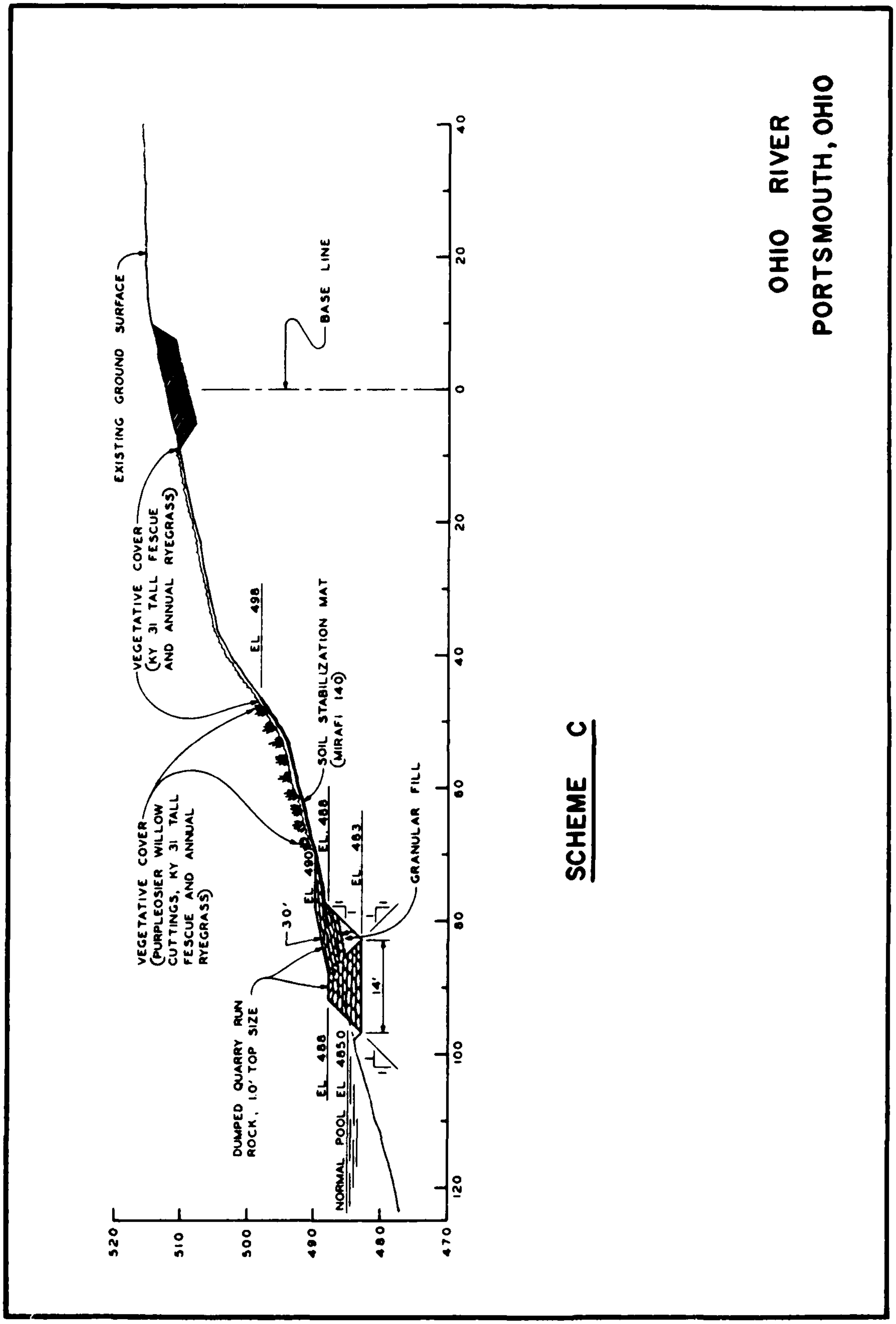

OHIO RIVER
PORTSMOUTH, OHIO
SCHEME C
EXISTING GROUND SURFACE
BASE LINE
VEGETATIVE COVER (KY 31 TALL FESCUE AND ANNUAL RYEGRASS)
EL 498
SOIL STABILIZATION MAT (MIRAFI 140)
VEGETATIVE COVER (PURPLEOSIER WILLOW CUTTINGS, KY 31 TALL FESCUE AND ANNUAL RYEGRASS)
EL 488
EL 490
EL 483
GRANULAR FILL
30'
14'
DUMPED QUARRY RUN ROCK, 1.0' TOP SIZE
EL 488
NORMAL POOL EL 485.0
520
510
500
490
480
470
40
20
0
20
40
60
80
100
120

EXHIBIT I-4

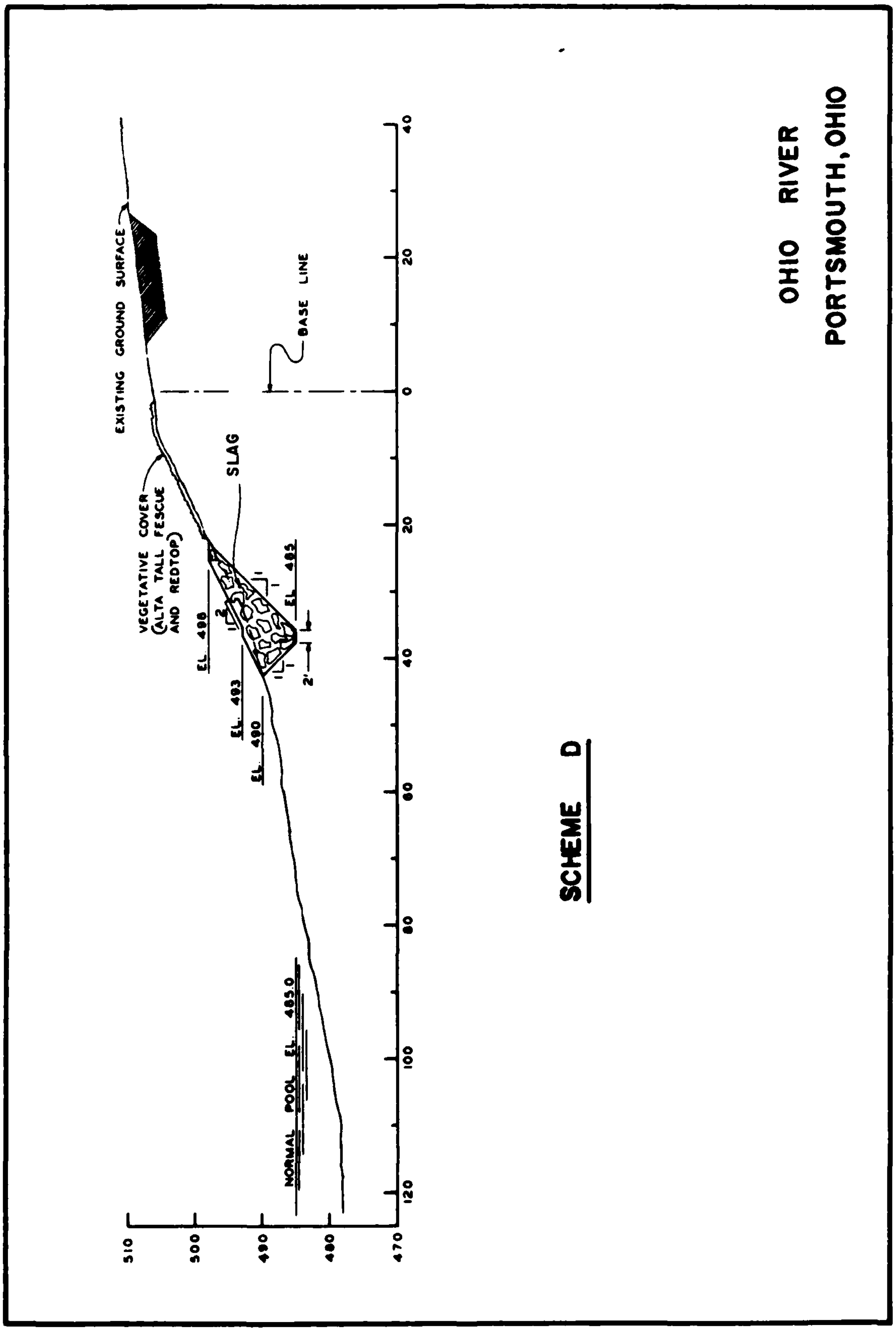

OHIO RIVER
PORTSMOUTH, OHIO
SCHEME D
EXISTING GROUND SURFACE
BASE LINE
VEGETATIVE COVER (ALTA TALL FESCUE AND REDTOP)
SLAG
EL 498
EL 493
EL 490
EL 485
2'
NORMAL POOL EL 485.0
510
500
490
480
470
120
100
80
60
40
20
0
20
40

EXHIBIT I-5

COST SUMMARY
Portsmouth, Ohio, Demonstration Project

ITEM	TOTAL COST	COMMENTS
Construction	$ 193,955	
Engineering & Design	49,870	
Supervision & Administration	6,675	
Monitoring	1,500	
Reconstruction	10,500	Stone, filter cloth, and vegetation materials lost due to high water during construction
TOTAL	$ 262,500	

CONSTRUCTION COST FOR EACH TREATMENT

Type of Protection	Cost per Lineal Foot	Cost per Square Foot
Scheme A: waste rock	$ 65.38	$ 0.73
Scheme B: 18" stone	114.52	1.15
Scheme C: 12" stone	141.14	1.76
Scheme D: slag	206.61	4.59

These costs include all preparation of slopes and installation

EXHIBIT I-6

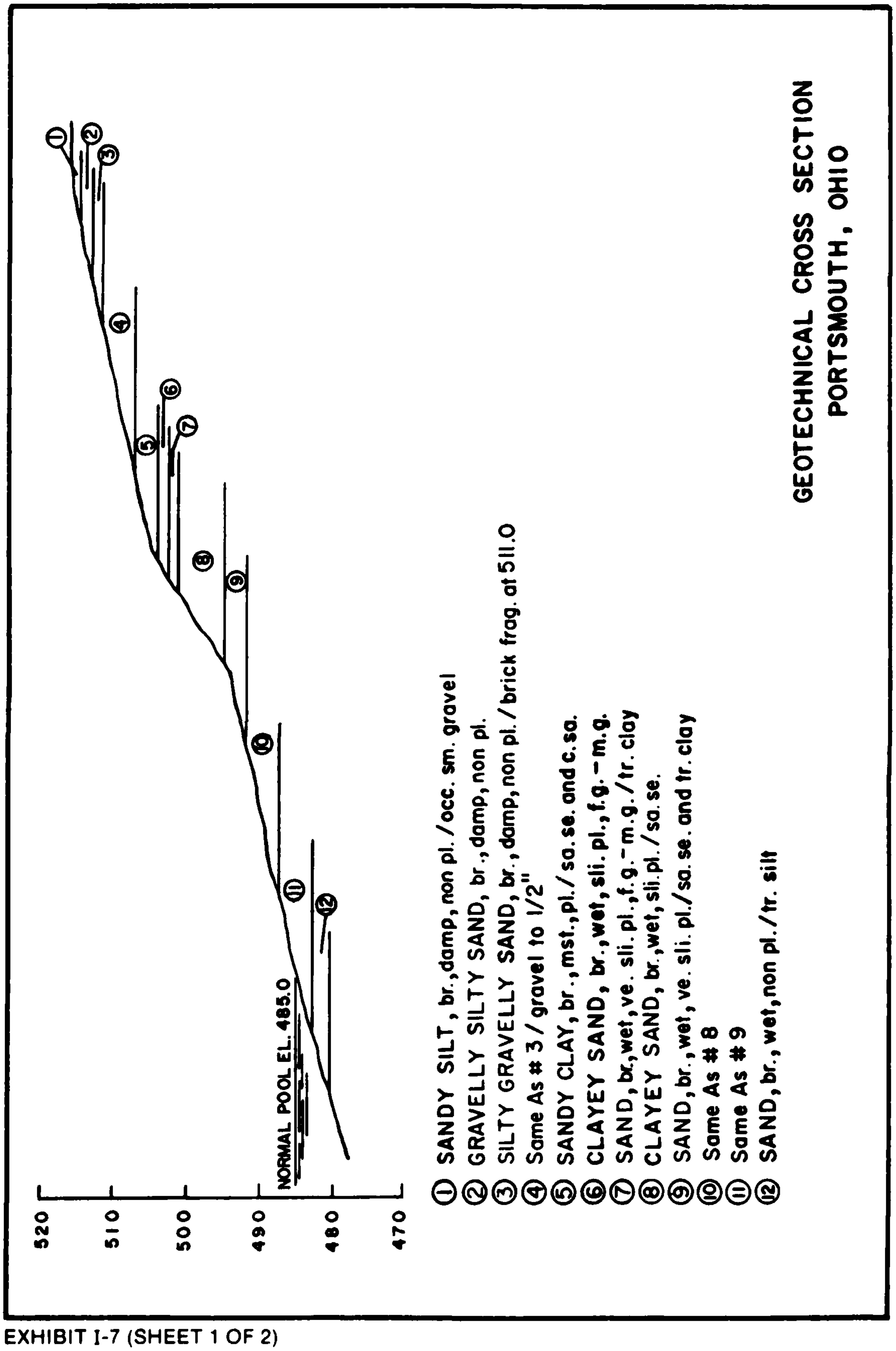


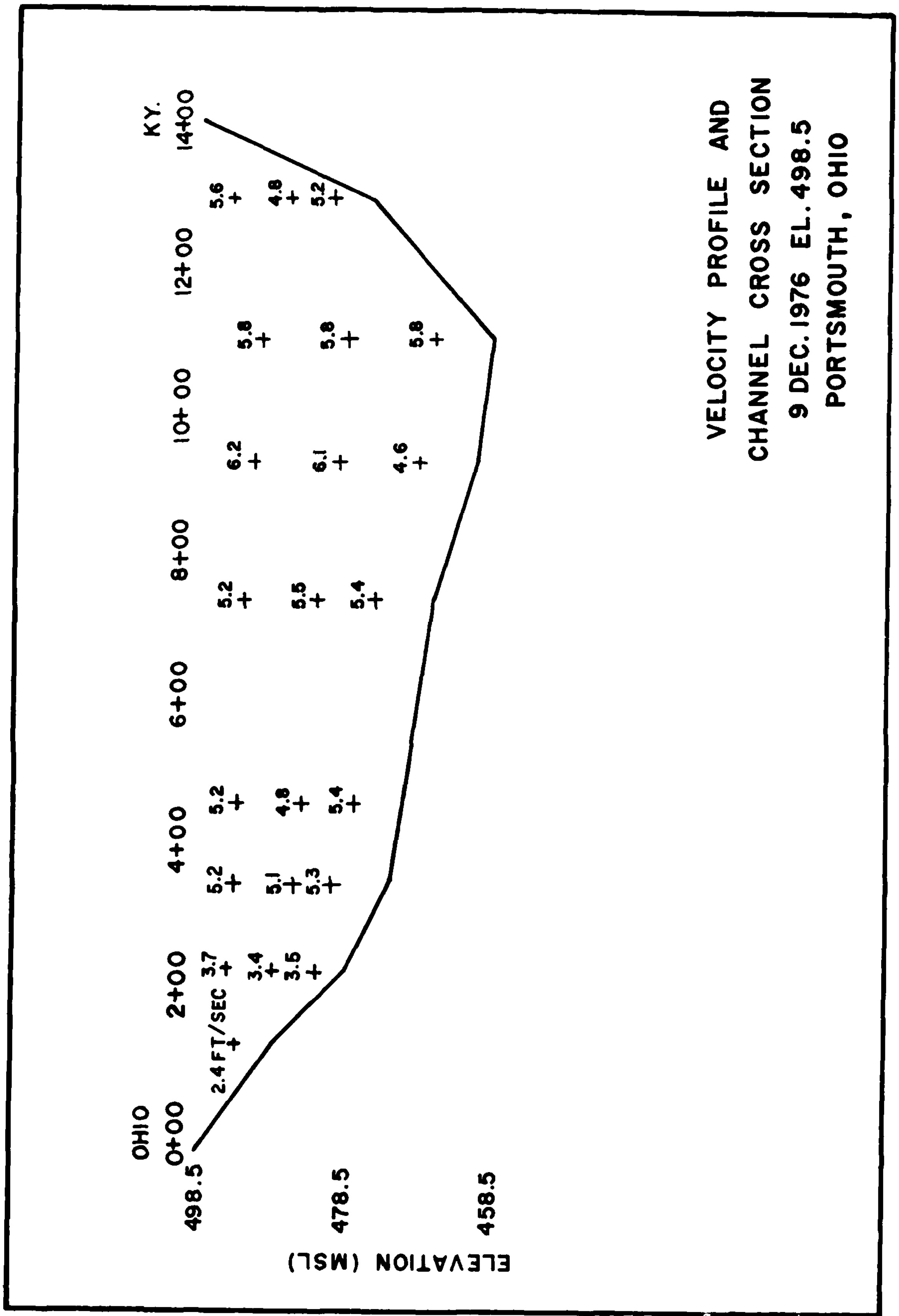
EXHIBIT I-7 (SHEET 1 OF 2)

ABBREVIATIONS

a.	angle
alt.	alternat(e)(ly)(ing)
amt.	amount
ang.	angular
approx.	approximate(ly)
ar.	argillaceous
aren.	arenaceous
asp.	asphaltic
b.	bone
ba.	banded(ing)
bd.	bed(ded)(ing)
bdr.	bedrock
bf.	buff
bk.	black
bky.	blocky
bkn.	broken
bl.	blue
bou.	boulder(s)
bre.	breccia(ted)
br.	brown
c.	coarse
ca.	calcareous
carb.	carbonaceous
cav.	cavern, cavity
cbl.	cobble(y)
ch.	chert
cl.	clayey
cle.	clean
coa.	coated(ing)
comp.	compact
conc.	concretion
cong.	conglomeratic
cont.	contains
cr.	crushed
crm.	crumbly
cst.	crystal(line)
cem.	cement(ed)
di.	dirty
dia.	diameter
diag.	diagonal
dis.	disintegrated
disc.	discontinuous
diss.	disseminated
dk.	dark
dn.	dense
dmp.	damp
ext.	extremely
f.	fine
fer.	ferruginous
fis.	fissile
fil.	filled(ing)
fos.	fossil(iferous)
frac.	fracture(d)
frags.	fragment(s)(al)
fri.	friable
f.w.	free water
g.	grain(ed)
gen.	generally
gn.	green
gr.	gray
gra.	gravelly
grad.	grading(ed)
G.W.	*ground water*
h.	hard
ha.	high angle
hi.	high(ly)(er)
hor.	horizontal(ly)
inc.	inclusions
incr.	increasing(ly)
inla.	interlaminated
intbd.	interbedded
irr.	irregular
jt.	joint(ed)
l.	little
la.	low angle
las.	laminat(ions)(ed)
lay.	layer(s)
le.	lean
lea.	leached
len.	lense(s)
lg.	large
lt.	light
m.	moderate(ly)
ma.	many
mas.	massive(ly)
mat.	material
mic.	micaceous
min.	mineralized
mos.	mostly
mot.	mottled
mst.	moist
mtx.	matrix
n.	near
nod.	nodule(s)
num.	numerous
o.	open
occ.	occasional(ly)
occu.	occurring
org.	organic
pa.	parting(s)
part.	particle(s)
pl.	plastic
peb.	pebble(s)
pk.	pink
pkt.	pocket(s)
pit.	pit(ted)
pn.	plane(s)
po.	porous
pt.	part(ly)
pyr.	pyrite(ic)
q.	quartzitic
r.	red
ro.	rock(s)
rot.	rotten(ed)
rou.	round(ed)
rt.	root(s)(let)
s.	soft
sa.	sandy
sat.	saturated
scat.	scattered
se.	seams
sev.	severely
sevr.	several
sh.	shaly
sil.	siliceous
sl.	silty
sli.	slight(ly)
slk.	slickensided
sm.	small
so.	some
sol.	solution
sta.	stain(ed)
stf.	stiff
stks.	streak(s)
str.	stringer(s)
sty.	stylolite(ic)
t.	thin
tho.	throughout
tk.	thick
tr.	trace
v.	variably
va.	variegated
ve.	very
veg.	vegetation
ver.	vertical(ly)
vu.	vuggy
w.	water
/	with
w.c.	water content
wd.	weathered
whi.	white
x-bd.	cross bedded(ing)
y.	yellow
zo.	zone

GEOTECHNICAL CROSS SECTION

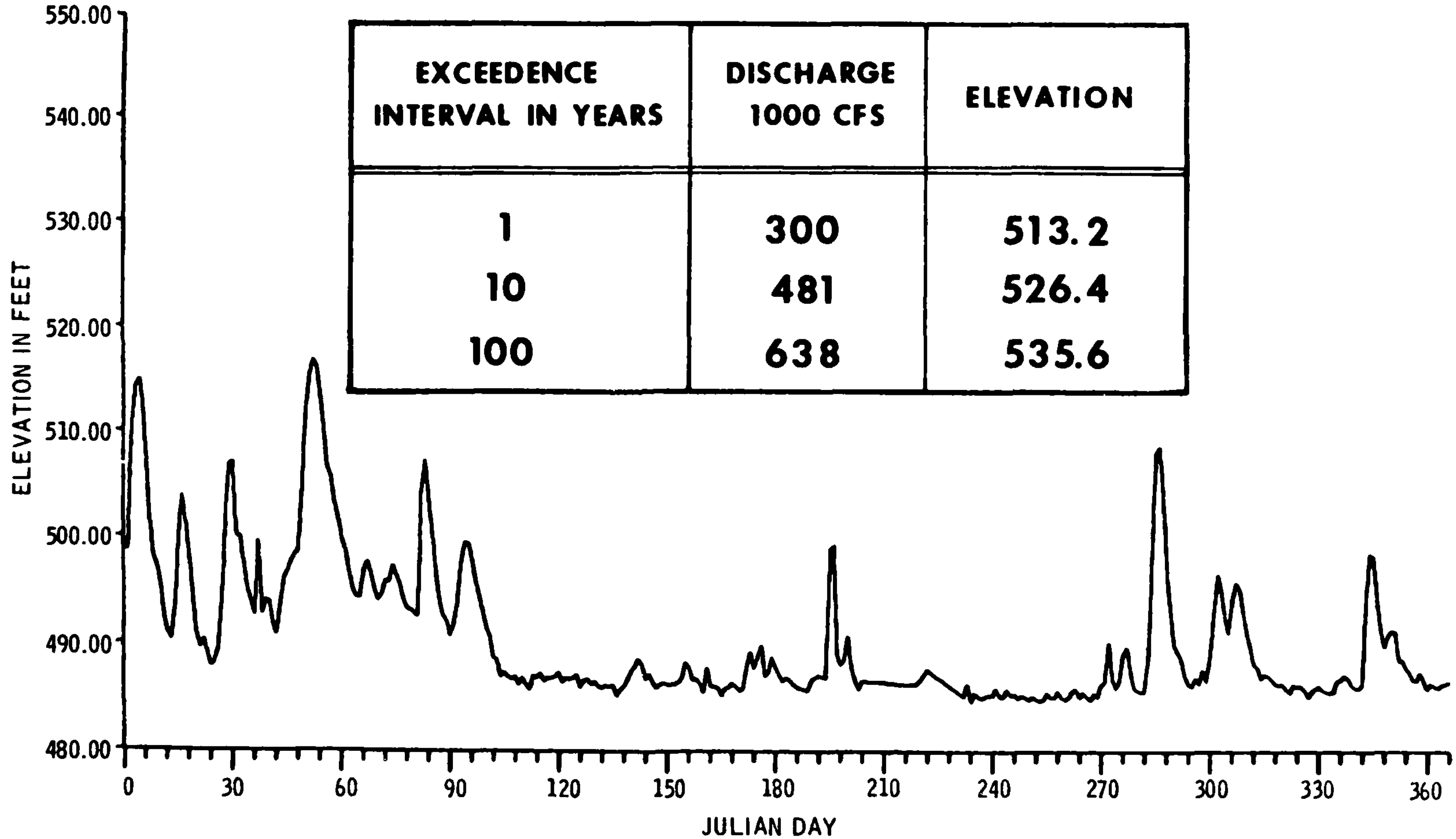
EXHIBIT I-7 (SHEET 2 OF 2)



VELOCITY PROFILE AND
CHANNEL CROSS SECTION
9 DEC. 1976 EL. 498.5
PORTSMOUTH, OHIO
ELEVATION (MSL)
498.5
478.5
458.5
OHIO
KY.
0+00
2+00
4+00
6+00
8+00
10+00
12+00
14+00
2.4 FT/SEC

EXHIBIT I-8

1976



EXCEEDENCE INTERVAL IN YEARS	DISCHARGE 1000 CFS	ELEVATION
1	300	513.2
10	481	526.4
100	638	535.6

OHIO RIVER

STAGE HYDROGRAPHS AT PORTSMOUTH, OHIO

EXHIBIT I-9 (SHEET 1 OF 5)

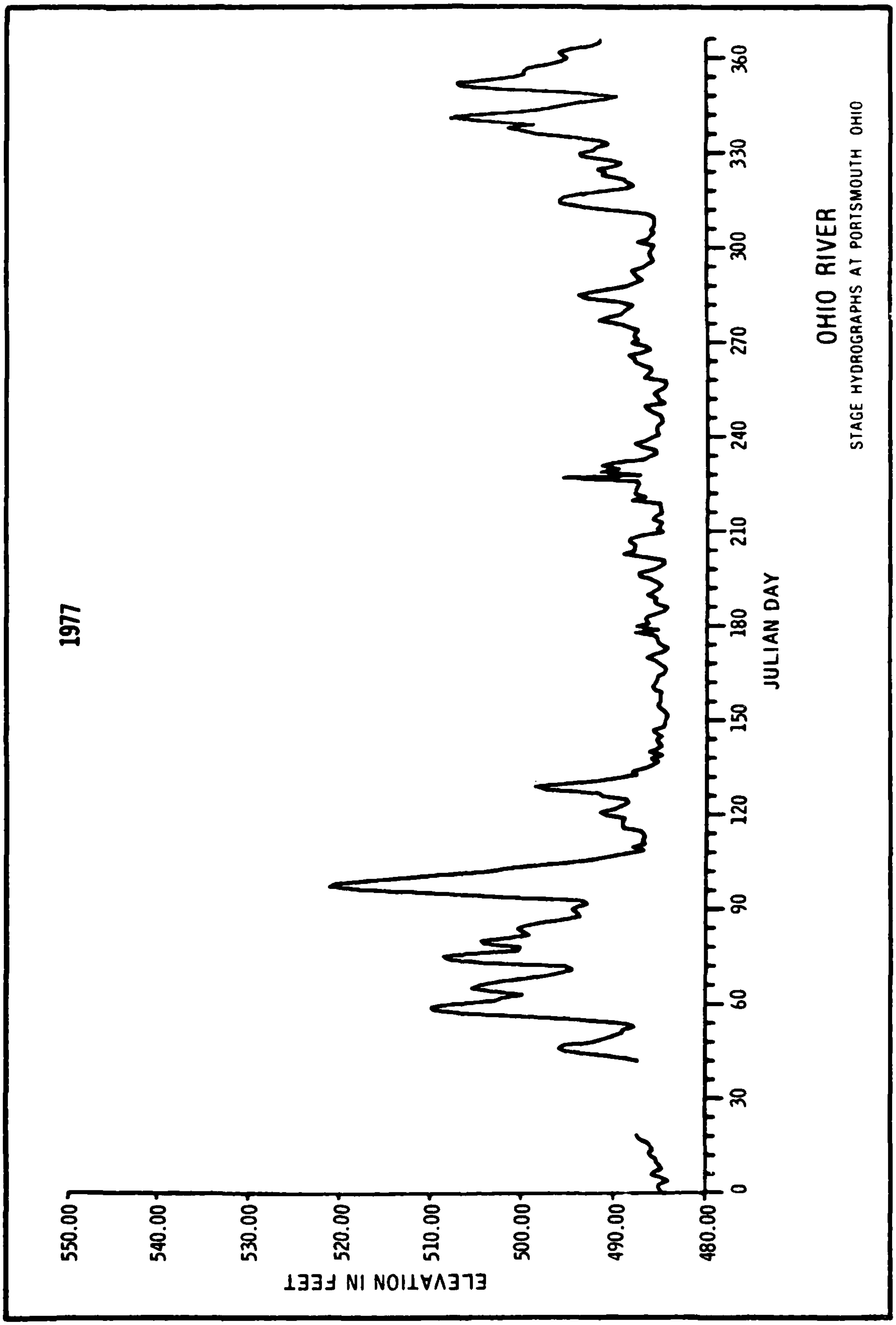


EXHIBIT I-9 (SHEET 2 OF 5)

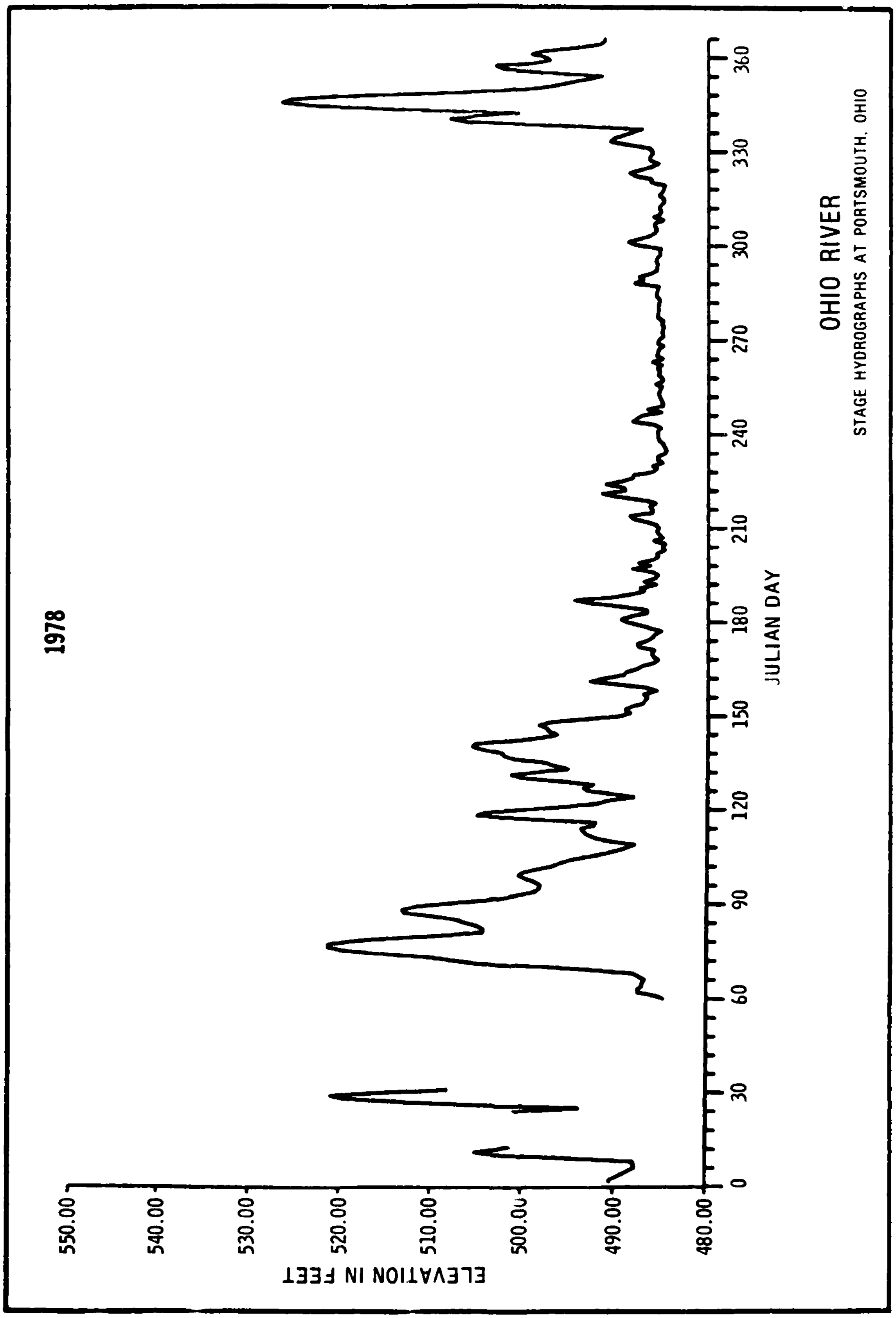


EXHIBIT I-9 (SHEET 3 OF 5)

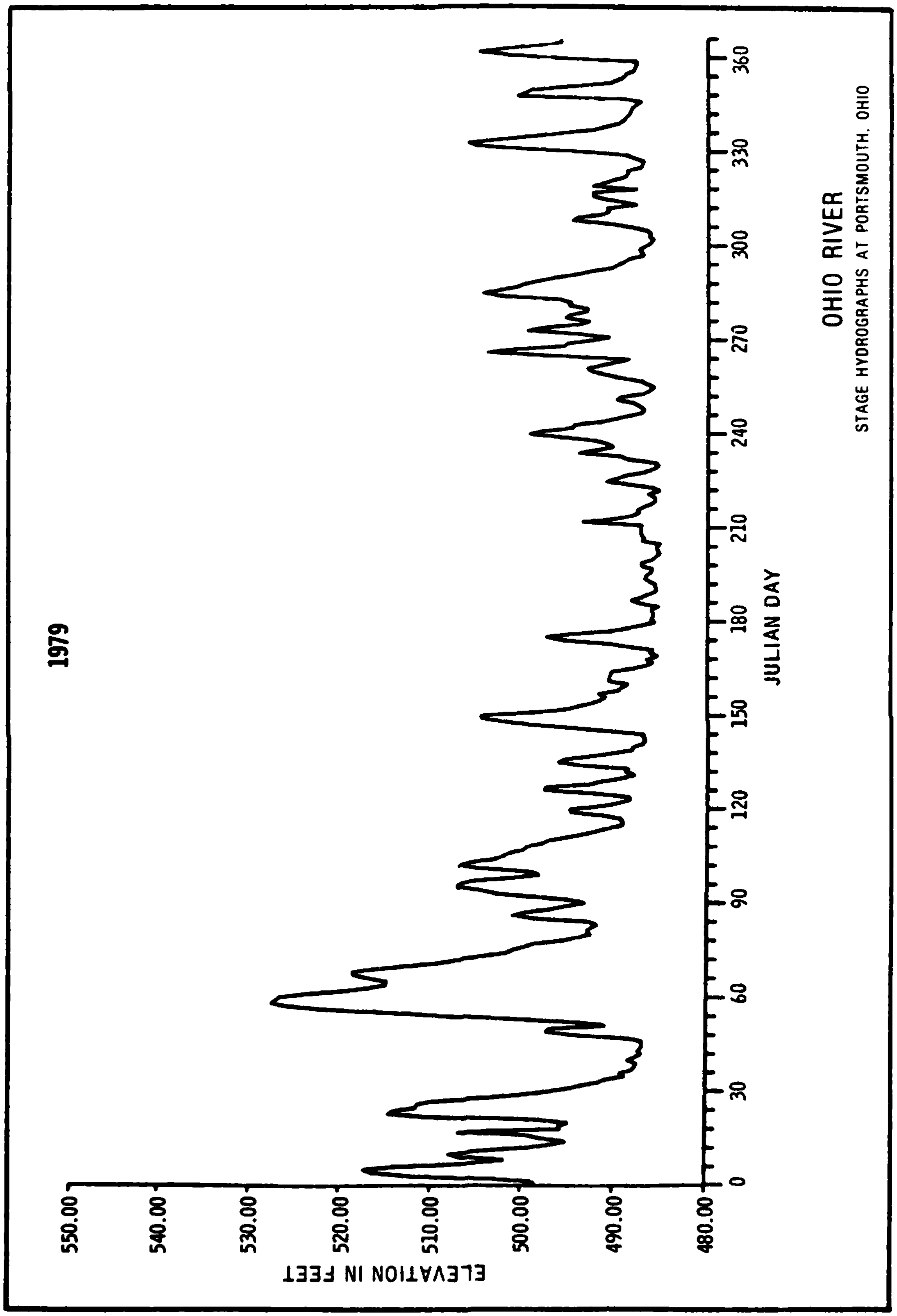


EXHIBIT I-9 (SHEET 4 OF 5)

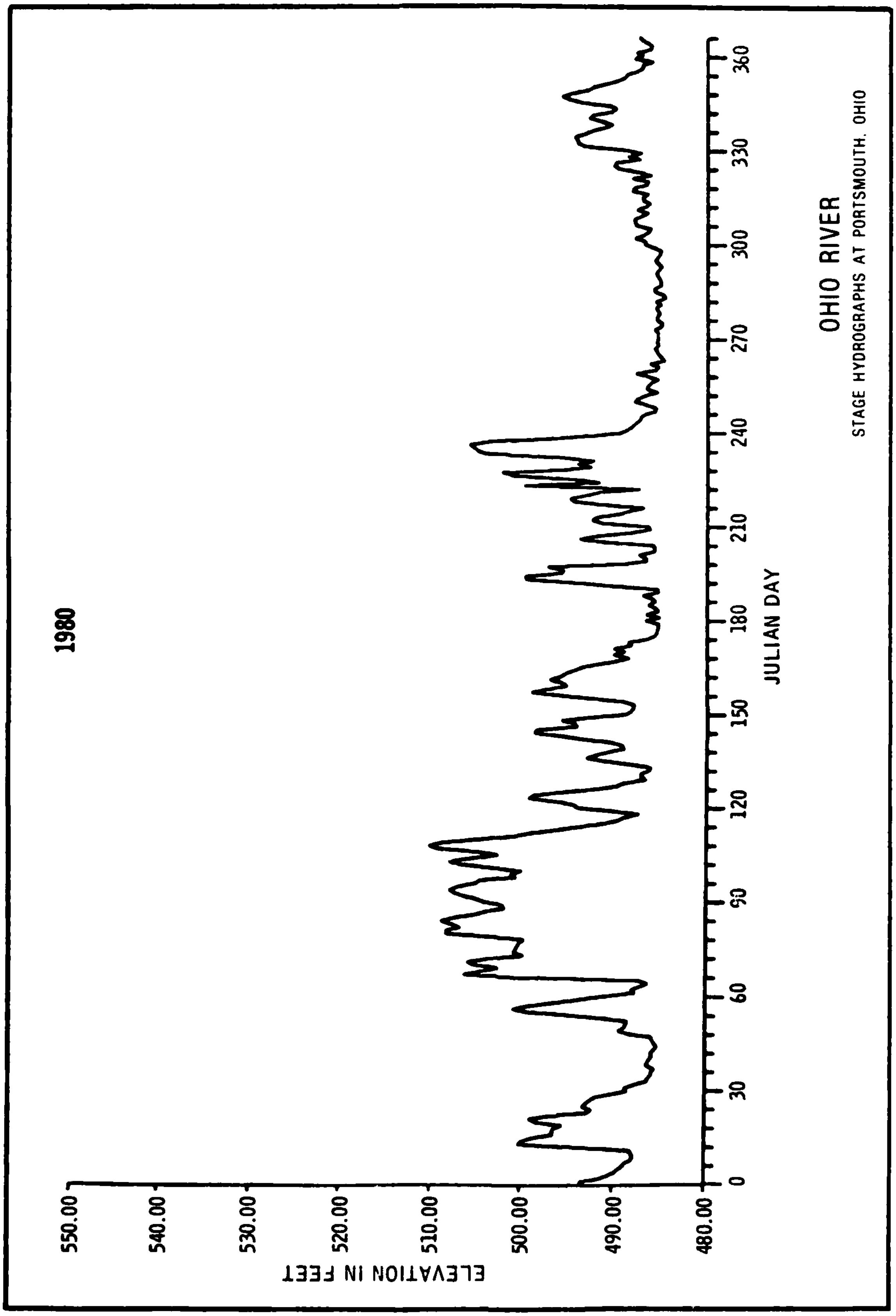
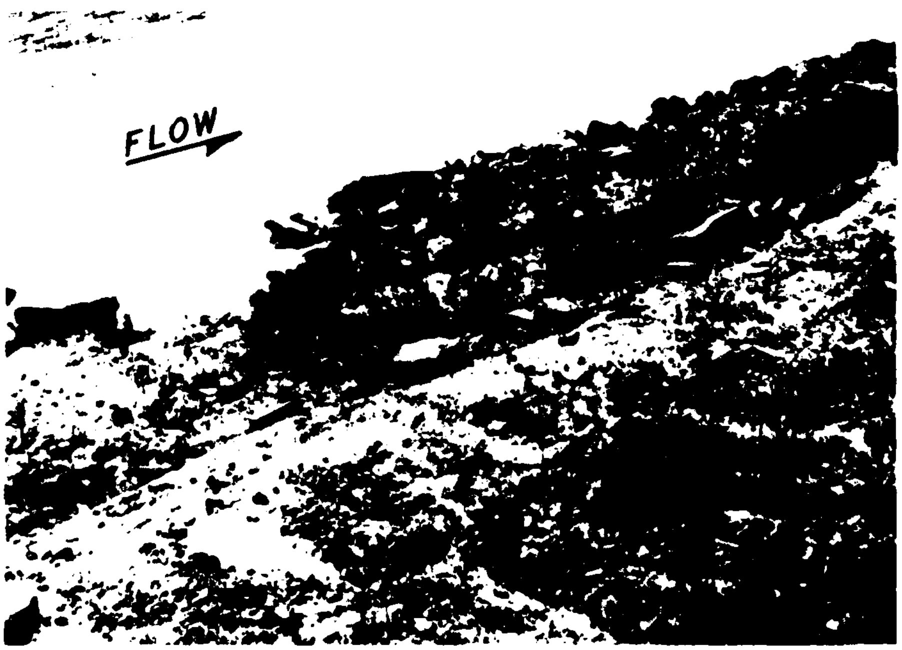


EXHIBIT I-9 (SHEET 5 OF 5)

SCHEME A: LOOKING DOWNSTREAM BEFORE CONSTRUCTION



SCHEME A: LOOKING DOWNSTREAM DURING CONSTRUCTION

EXHIBIT II-1

SCHEME A: LOOKING DOWNSTREAM AFTER CONSTRUCTION

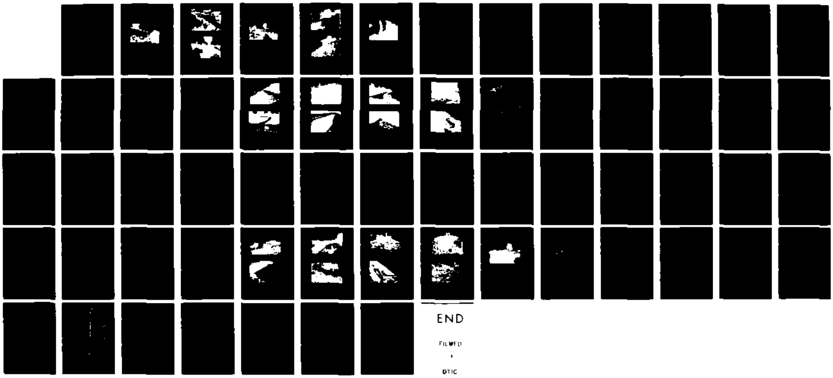
EXHIBIT II-2

SCHEME B: LOOKING DOWNSTREAM BEFORE CONSTRUCTION

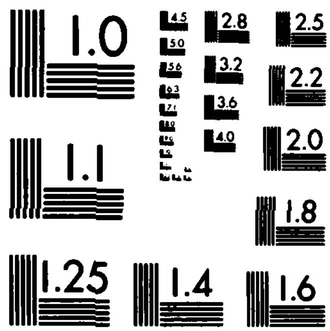
SCHEME B: LOOKING UPSTREAM DURING CONSTRUCTION

EXHIBIT II-3

AD-A121 134 THE STREAMBANK EROSION CONTROL EVALUATION AND 4/4
DEMONSTRATION ACT OF 1974 S..(U) ARMY ENGINEER
WATERWAYS EXPERIMENT STATION VICKSBURG MS HYDRA..
UNCLASSIFIED M P KEOWN ET AL. DEC 81 WES/TR/H-77-9-APP-D F/G 13/2 NL



END
FILMED
DTIC



MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A

SCHEME B: LOOKING UPSTREAM AFTER CONSTRUCTION

EXHIBIT II-4

SCHEME C: LOOKING DOWNSTREAM BEFORE CONSTRUCTION

SCHEME C: LOOKING UPSTREAM DURING CONSTRUCTION

EXHIBIT II-5

SCHEME C: LOOKING UPSTREAM AFTER CONSTRUCTION

EXHIBIT II-6

SCHEME D: LOOKING DOWNSTREAM BEFORE CONSTRUCTION

SCHEME D: LOOKING DOWNSTREAM DURING CONSTRUCTION

EXHIBIT II-7

SCHEME D: LOOKING DOWNSTREAM AFTER CONSTRUCTION

EXHIBIT II-8

OHIO RIVER
MOSCOW, OHIO

Section 32 Program Streambank Erosion Control
Evaluation and Demonstration Act of 1974

OHIO RIVER AT MOSCOW, OHIO
DEMONSTRATION PROJECT PERFORMANCE REPORT

I. INTRODUCTION

1. Project Name and Location.

Moscow, Ohio, Protection Works, Ohio River at Mile 442.5, Moscow, Ohio. Plate 1 shows the location plan and vicinity map for the project.

2. Authority.

Streambank Erosion Control Evaluation and Demonstration Act of 1974, Section 32, Public Law 93-251.

3. Purpose and Scope.

This report describes a bank erosion problem, the types of bank protection used and a performance evaluation of a demonstration project on the Ohio River constructed and maintained by the Louisville District.

4. Problem Resume.

The project is located on the right (north) bank of the Ohio River within the Village of Moscow, Ohio, at River Mile 442.5 as shown on the location map in Plate 1. Proposed stabilization measures would protect about 650 feet of residential frontage upstream from a 300-ft public wharf area and about 650 feet of residential frontage downstream from the wharf. The wharf area, paved with cobblestones during the last century, is relatively stable. The area of recession is the former site of Water Street and is mostly within the right-of-way of Water Street. In recent years, stone retaining walls built along the land side of this right-of-way have begun to fail due to recession of the riverbank within the right-of-way. The amount of bank recession upstream and downstream from the wharf area appears to be about 50 feet. Since 1970,

several measures have been taken by local agencies and private owners to stabilize the banks. These include: (1) Construction of a derrick stone dike on the benched-out area at the upstream limit of the problem area in order to protect two houses at the eastern limit of Moscow. (2) Riprapping of the steep portion of the bank at the eastern limit of the problem area to protect the same two houses. (3) Riprap, tires, and a board fence have been placed riverward of a house at Walnut Street. (4) Willow shoots have been planted at random along the benched-out area of the shore for the entire length of the problem area. However, these piecemeal attempts to solve the problem have not resulted in stopping the erosion. If no additional work were done, the bank would continue to be undermined and the existing retaining wall along the steep portion of the bank would fail. This would expose the foundation of 14 residences, several of which are historically significant.

II. HISTORICAL DESCRIPTION

5. Stream.

a. Topography. Moscow, Ohio, is located about midway along the 981 mile length of the Ohio River. Around Moscow, the river flows in a generally northwest direction. There are several gradual bends in the river along the southeastern Ohio border. Sharp bends are not present in the area as they are in many other areas of the river. The topography of the area is moderately rolling to steep. Much of the terrain is forested. Stream meander has been minor compared to other areas downstream which are generally flat and have a deep covering of alluvial overburden. The riverbank at Moscow is about 45 feet above Markland Dam normal pool 455. Plate 9 is a full natural river cross section at the project site.

b. Geology. The Ohio River in this reach is near the southern limit of Illinoian glaciation and follows generally the course of the ancestral Cincinnati River.

Bedrock in the area is Upper and Middle Ordovician Age limestone, shales and siltstone. In the valley, bedrock is the Point Pleasant formation of limestones with thin shales and siltstone beds; in the surrounding hills, the

bedrock is the Kope formation consisting of shales with thin limestone beds. Alluvial deposits in the valley consist of 45 ± feet of silts, clays, sand and gravel. Plate 10 is natural section at the project showing soil compositions. This data was obtained by field inspection by a Geotechnical Engineer.

c. Locality, Development and Occupation. The Ohio River valley in the vicinity of the demonstration site has developed a diverse industrial character. There is a variety of occupations including: farming, small private factories and service companies, large industrial complexes, and various public service companies. Moscow is about 26 miles upstream from Cincinnati, Ohio. The two are connected via State Highway 52 and many of Moscow s inhabitants commute to work in Cincinnati. The terrain around Moscow is moderately rolling to heavy rolling which does not lend itself to large farm complexes. Farms are generally fewer in number and smaller in size than the other areas of the Ohio valley downstream. Most common crops are corn, tobacco and beans. Considerable cattle are also raised. A nuclear powerplant being constructed immediately downstream from Moscow has been annexed by the Village.

Moscow itself is quite small, less than 1,000 persons. There are no large factories. People either work in very small local shops or commute to locations in greater Cincinnati. The population has changed very little in the last few years. Moscow is in Clermont County with Batavia being the County Seat about 30 miles to the north. Plate 1 shows the general location of Moscow.

d. Hydrologic Characteristics. The Ohio River flows in a southwest direction through mideast and midwest states. The river is 981 miles long. Zero mileage starts at the headwaters of this stream which is in the confluence of the Allegheny and Monongahela Rivers. The river valley experiences somewhat varying weather patterns since the eastern part of the basin is further north than the western portion. Winters in the valley are generally moderately cold with temperatures below zero occurring occasionally in the southern-western portion and occurring more frequently in the northern-eastern portion. Ice jams occur occasionally in the northern valley

and very seldom in the southern portion. Average slope of the river is 0.3 feet per mile. The greatest flood on record was the 1937 flood. Discharge in this flood near Moscow was 823,000 cfs. Plate 11 shows various flood profiles and the normal pool level (455) for the project vicinity. Average flow near Moscow is about 89,000 cfs.

e. Channel Conditions. The Ohio River has been an important artery since prehistory and has undergone navigation improvements since 1824 when Congress provided for removal of obstructions such as bars and snags. For many years, river navigation was facilitated solely by open channel improvements. In addition to removal of channel obstructions, stone training dikes were constructed at various bars in order to constrict the channel and increase the scour of the river. The first movable dam on the Ohio River was located at Davis Island, 4.7 miles below Pittsburgh, and opened to commerce October 7, 1885. A system of locks and movable dams was eventually constructed along the entire Ohio River. These early dams incorporated a navigable pass to provide a channel for open river navigation during periods of high flow. A series of wickets, heavy timber shutters, were raised to impound water as needed to maintain a navigation pool. When not required, the wickets would lie flat at such a depth as to offer no obstruction to free navigation through the pass. Replacement of these original navigation dams with fixed, gated structures having higher lifts has been ongoing. Markland Dam, downstream of project, was placed in operation in 1965. Meldahl Dam, upstream of project, was placed in operation in 1965. These high lift dams maintain 9 foot navigation depths all along the river. Depths immediately upstream of these new dams range from 25 to 40 feet. The width of the river channel averages almost roughly 3,000 feet. Plate 9 is a natural channel cross section at the project site.

f. Environmental Considerations. Because of the frequent inundation and constant erosion of the bank, vegetation is sparse and limited in diversity especially at the lower elevations. On the beach itself, the vegetation consists primarily of willows and a few scattered perennials and annuals. Higher up the bank, the vegetation becomes denser and includes such species as johnson grass, panic grass, lamb's quarter, sunflower, ragweed, and occasional patches of equisetum. The equisetum, as well as certain other

species, no doubt derived their moisture requirements from the numerous residential outfalls located along the bank. Along the upper edge of the slope and the bank top, the vegetation consists of typical flood plain species including silver maple, hackberry, ash, elm, and black walnut. Based on the existing habitat conditions, the study area is judged to support some residential tolerant songbirds and to serve as a "pass through" area for other species. An occasional rabbit, rodent, or reptile might also be supported within the area.

In accordance with Federal cultural resource legislation, an evaluation was made to determine the impact of the proposed project on archaeological, historic, paleonlogical, and architectural resources. A review of the University of Cincinnati archaeological site survey files revealed no sites within the project area. During the course of the field reconnaissance, a number of bones were recovered which have been tentatively identified as belonging to Bison. No prehistoric cultural materials were found within the project area. Several of the 14 residences, which are threatened by the eroding bank, have local historical, as well as architectural significance. None of these structures will be adversely affected by project construction.

The proposed project will exert short term adverse impacts on water quality during project construction as a result of increased turbidity. The long term impact on water quality should be positive as a result of decreased susceptibility of the bank to massive failure and erosion which will substantially lessen localized river turbidity. There will also be a temporary increase in noise and erosion and a decrease in air quality as a result of activities associated with construction. There will be no long term adverse impacts from these activities. The impact on natural vegetation and fauna will be minimal. A portion of the project area will be stabilized by regrading and planting of selected species. Whenever possible, the existing vegetative cover will be retained. The long term stability to be provided by the project should enhance the area from the standpoint of providing stabilized habitat conditions for wildlife.

From a socioeconomic standpoint, the project will be beneficial by providing protection to 14 residential structures, several of which have local

historical significance. Implementation of the project will not have any long term significant adverse effect on air, noise, water quality resources and aesthetics.

6. Demonstration Site Test Reach.

a. Hydrologic Characteristics. The Moscow, Ohio project is located on the right bank alluvial flood plain of the Ohio River, just upstream of the City of Moscow. The Ohio River at this point flows northward in a generally narrow valley. The river at the project site is approximately 1500 feet wide and the flood plain is 2500 feet wide. The slope on the Kentucky side rises steeply from the Ohio River to elevations above 800 feet. The alluvial flood plain is fairly flat, with an elevation of 500 feet, about 45 about the normal pool of Markland Dam. The hills on the Ohio side of the river rise steeply from the flood plain to approximately the same elevations as on the Kentucky side of the river. Temperatures in the area are relatively moderate, rarely above 100°F and only occasionally below 0°.

b. Hydraulic Characteristics. The Moscow, Ohio, site is located in a relatively straight portion of the Ohio River (Mile 442.5). Stream velocity ranges from about 1 foot per second at normal pool (455.0) to 5 feet per second for high water. Ordinary High Water (OHW), 100-year flood, and record 1937 flood elevations at the site are 475.3, 506, and 516, respectively. Moscow is 89.1 miles above Markland Dam (normal pool 455.0) and 6.4 miles below Meldahl Dam. An elevation-frequency curve is given on Plate 16. Plate 9 is a full natural cross section at the project site. Plate 11 is an Ohio River water surface profile of the river in the area. Elevation hydrographs for the Markland Pool (years 1977-1980) are shown on Plates 12-15.

c. Riverbank Description. The study area consists of an eroding bank on the edge of a narrow flood plain of the Ohio River. The bank consists of beach less than 100 feet in width with a 1 on 5 slope, backed up by a steep bank of about 20 feet in height with a 1 on 1 slope. Both the beach and the bank have been benched by the effects of wave action. Soil consists of alternating seams of sandy silt and clay. Portions of the upper section of the bank are supported by brick and stone retaining walls. There is a 400-

foot public wharf area which lies between eroding bank areas. It is composed of cobblestones which were hand placed in the last century. These have been partially paved over with asphalt. Bank recession has not occurred in the wharf area but is obvious on the banks of either side of it. The riverfront at Moscow was not affected by the raising of Markland Pool in 1963 because a previous dam had caused a normal pool of 455 at Moscow prior to impoundment of Markland Dam.

III. DESIGN AND CONSTRUCTION.

7. General. Because of the rather gentle slope of the riverbank, a design was developed which would preserve the whole bank and require extensive protection at the lower level. This plan is shown on Plates 3 and 4. The lower bank would have stone protection, and the upper bank would be graded and protected by vegetation. Four different types of vegetation protection were tried for the upper bank. These are shown on above plates. Ice problems are not normally encountered at the site. Therefore, design of protection to withstand ice forces was not incorporated.

8. Basis for Design. The riprap design of the lower bank was used because it was relatively cheap and was easy to install at this site using a dozer. Also, this would hopefully provide a stable lower slope so that adequacy of the different vegetation covers on the upper bank could be compared.

9. Construction Details. Plates 5 through 8 show sections of four schemes used. Placement of the toe protection was done by dozer. Grading of upper slopes was also done by dozer. Hand labor would be used to seed the area and plant vegetation.

The work was accomplished in four areas each using a different type of bank protection for testing purposes. Beginning at the upstream limit of the project, Type I, about 670 cubic yards of stone riprap toe protection was installed up to elevation 458 along 300 feet of shore front. The shore area between elevations 458 and the top of the bank (about elevation 485) was protected by a combination hydro-seed and straw with asphalt emulsion.

The next 350 feet, Type II, of shore is protected by a riprap toe up to elevation 458. The shore area between elevations 458 and 485 is protected by plantings through a mesh combining nylon and paper (hold grow) and a 4-inch layer of granular bedding. This reach required 780 cubic yards of riprap, 280 cubic yards of bedding, and 2,530 square yards of hold-grow. The next 300 feet is a public wharf area built of hand-placed cobblestones partially paved. Riprap is to be used to repair areas where cobbles have come out of place. About 500 cubic yards of riprap will be required for this purpose.

The next 350 feet of riverbank, Type III, is protected by a riprap toe up to elevation 462. The shore area between elevations 462 and 485 is protected by selected plantings through excelsior erosion control mats and a 4-inch layer of granular bedding material. This reach required 910 cubic yards of riprap, 210 cubic yards of bedding material and 1,940 square yards of excelsior erosion control mats.

The remaining 300 feet (to the downstream limit of the project), Type IV, is protected by a riprap toe to elevation 462. The shore area between elevation 462 and 485 is protected by selected plantings into granular bedding material stabilized by mulch. This reach required 780 cubic yards of riprap and 180 cubic yards of gravel bedding material.

10. Cost. The total cost of the project to date is $352,000 including engineering, construction, design and supervision. Some seeding and willow tree plantings have not yet been done by the Corps. Three monitoring inspections have been made so far. The table below shows actual construction costs expended to date. Total costs including supervision, administration, engineering, design, and construction is also given.

Protection Type	Construction Cost/Square Foot	Construction Cost/Linear Foot	Total Cost/Linear Foot
Type I	.034	2.40	$ 69.
Type II	.111	5.60	148.

Protection Type	Construction Cost/Square Foot	Construction Cost/Linear Foot	Total Cost/Linear Foot
Type III	.155	8.41	151.
Type IV	.067	3.24	145.
Riprap (lower bank)	2.28	79.65	--

IV. PERFORMANCE OF PROTECTION.

11. Monitoring Program. Elements of the monitoring program are summarized in Plate 2. The site has only been monitored on three occasions so far. Monitoring will continue through September, 1983. A velocity instrument was not used because stream velocity is not critical in this case. Velocity is estimated by engineers during inspections. Pool levels are obtained from the Beckjord Power Plant gage just downstream.

12. Evaluation of Protection Performance. By 22 January 1981, the project was complete except for seeding and willow tree planting. Photos 4 and 5 show "hold-grow" cloth and straw areas which river flow had damaged. They are not able to withstand river flow. During early June 81 high water, the "hold-grow" and straw were totally washed away. Also, some sloughing of the upper bank at downstream end of project had occurred during the June 81 high water. This water reached elevation 485 . Lower level areas actually had sediment deposits. All willow tree seedlings were either covered by sediment or washed away.

13. Rehabilitation. No rehabilitation has been done and it appears that none will be required. Some minor repair of upper slopes on downstream half of project may be required.

14. Summary of Findings. It is too early to even speculate on the relative effectiveness of the various types of vegetations used. It is known, however, that the nylon and paper mesh and straw do not withstand normal high water conditions. The riprap toe does appear quite stable at this time. Because of

the relative gentle slope of the earth bank, vegetation will probably take hold and maintain bank stability. Future monitoring inspections will be required to verify this. Possible problem areas at the site could be at the upstream and downstream ends of the project and where the gradually sloping bank meets the steeper banks near the residences. The June 81 monitoring inspection showed some sloughing taking place along the base of the steeper upper bank near residences. This appeared to be caused by high water flows and by "piping" of water through sandy areas of the ground. Photo 7 is a typical example of this problem area. Photo 8 shows the upstream portion of project where "hold-grow," straw, and willows were washed out by high water. Overall stability of this area appears good nevertheless. Riprap toe all along project was in excellent condition.

PHOTO NO. 1. 22 Jan. 81. Second Monitoring inspection. Looking downstream (Stations 20+40-27+30).

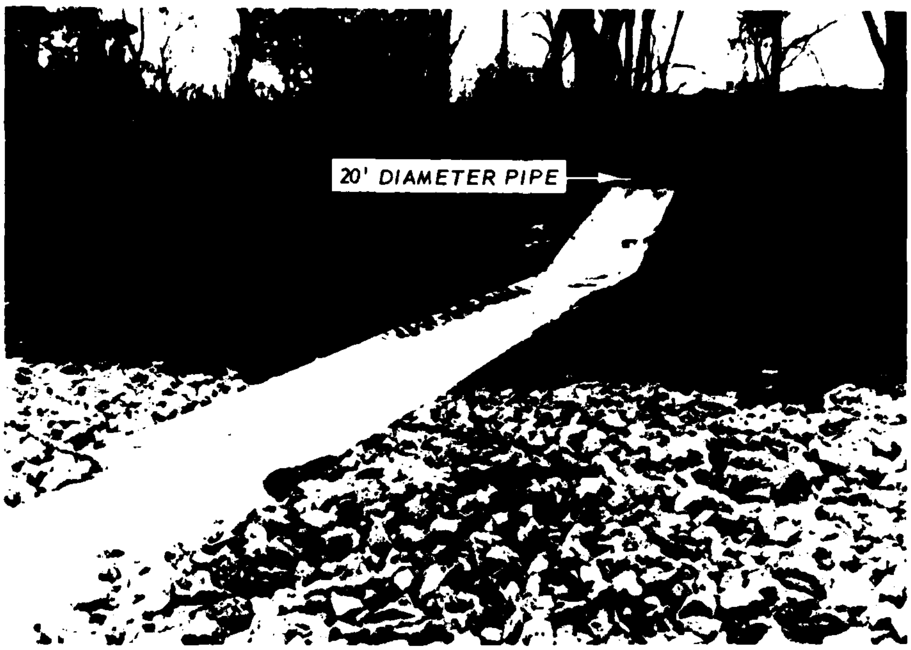


PHOTO NO. 2. Concrete paved outlet of small diameter clay pipe, Station 25+00.

PHOTOS 1 AND 2

PHOTO NO. 3. 22 Jan. 81. Second Monitoring inspection. Typical grading showing taper to upper bank (Stations 21+00-27+00).

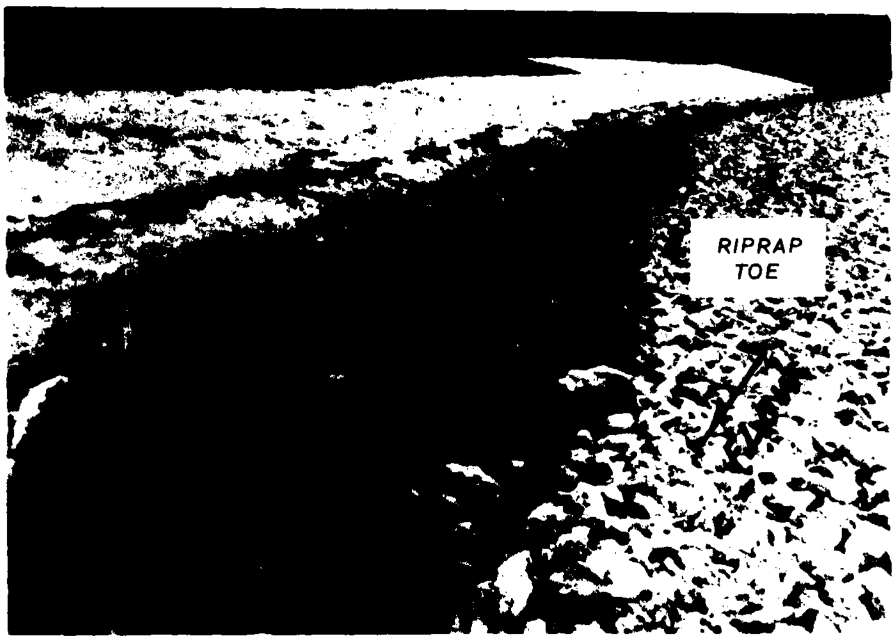


PHOTO NO. 4. 22 Jan. 81. Second Monitoring inspection. Closeup of "Hold Grow" mat--cannot withstand river current.

PHOTOS 3 AND 4

PHOTO NO. 5. 22 Jan. 81. Area upstream of cobblestone warf (Stations 10+80-16+50).

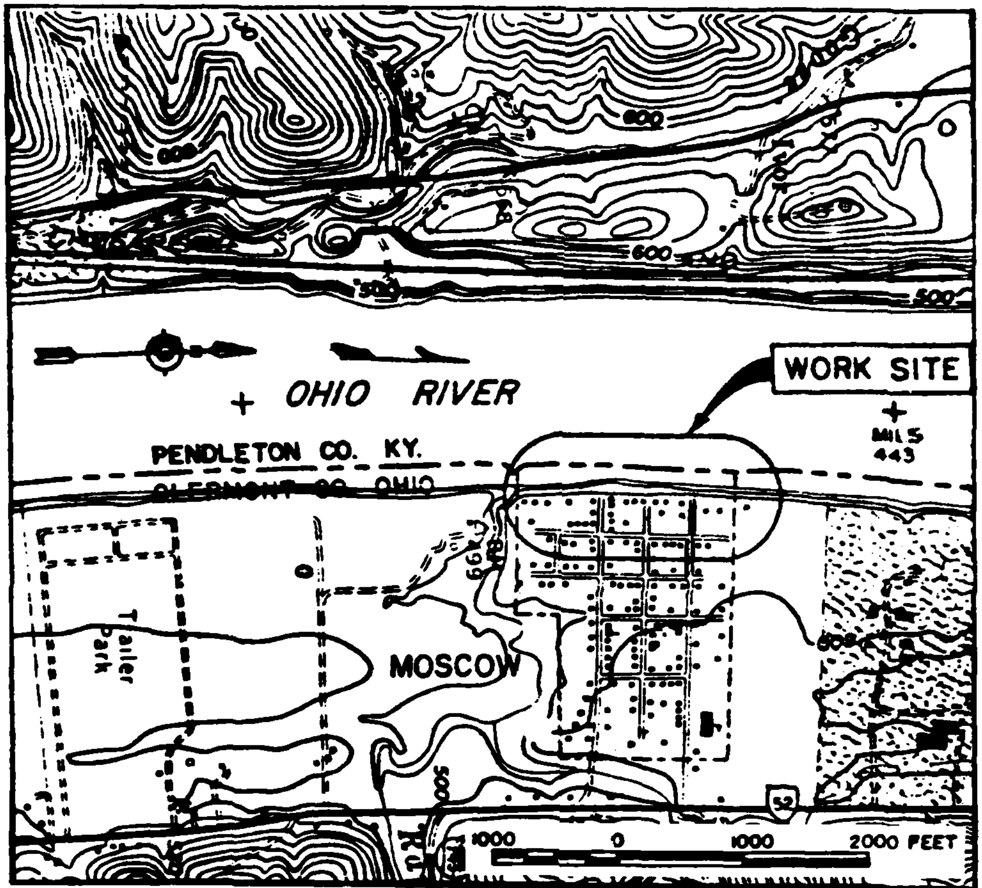
PHOTO NO. 6. Upstream end of stone protection where it ties into upper bank perpendicular to river flow.

PHOTOS 5 AND 6

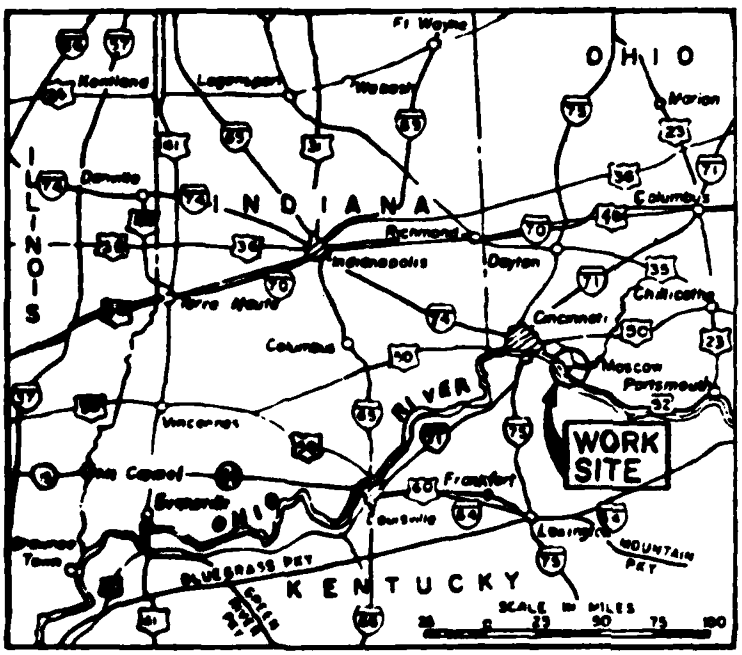
PHOTO NO. 7. Typical sloughing of upper bank along downstream half of project. (June 1981)

PHOTO NO. 8. Upstream half of project where "Hold-Grow" had been placed. High water washed out the hold-grow. (June 1981)

PHOTOS 7 AND 8



LOCATION PLAN



VICINITY MAP

MOSCOW, OHIO SITE
LOCATION PLAN
AND
VICINITY MAP

PLATE 1

Parameter	Item	Frequency
Geometry	1. Overbank cross sections thru various types of protection used. See Plates 5 thru 8.	Once-signif. changes to be resurveyed.
	2. Full channel cross section. Plate 9.	Once
	3. Ground photos from fixed reference points.	Quarterly
Climate	1. Air temperature, precipitation, wind.	Continuous
	2. Ice conditions, snow cover noted from visual observations.	As available
Hydraulics	1. River stage record (Beckjord Power Plant gage unit upstream).	Daily
	2. Stream velocity (estimated from observation).	Quarterly
	3. Wave height (fixed staff gage).	Quarterly
	4. Other miscellaneous river conditions: current direction, turbidity, etc.	Quarterly
Streambank Protection	1. Monitor dimensional changes of marked structural and vegetal units through photos and manual measurement.	Quarterly
	2. Observe durability of marked units of structural material (qualitative).	Quarterly
	3. Observe condition of marked plants.	Quarterly
	4. Record initiation and measure progression of failures in bank protection.	Quarterly
Geology and Soils	1. Materials properties testing.	Once

MOSCOW, OHIO
DATA COLLECTION TABLE

PLATE 2

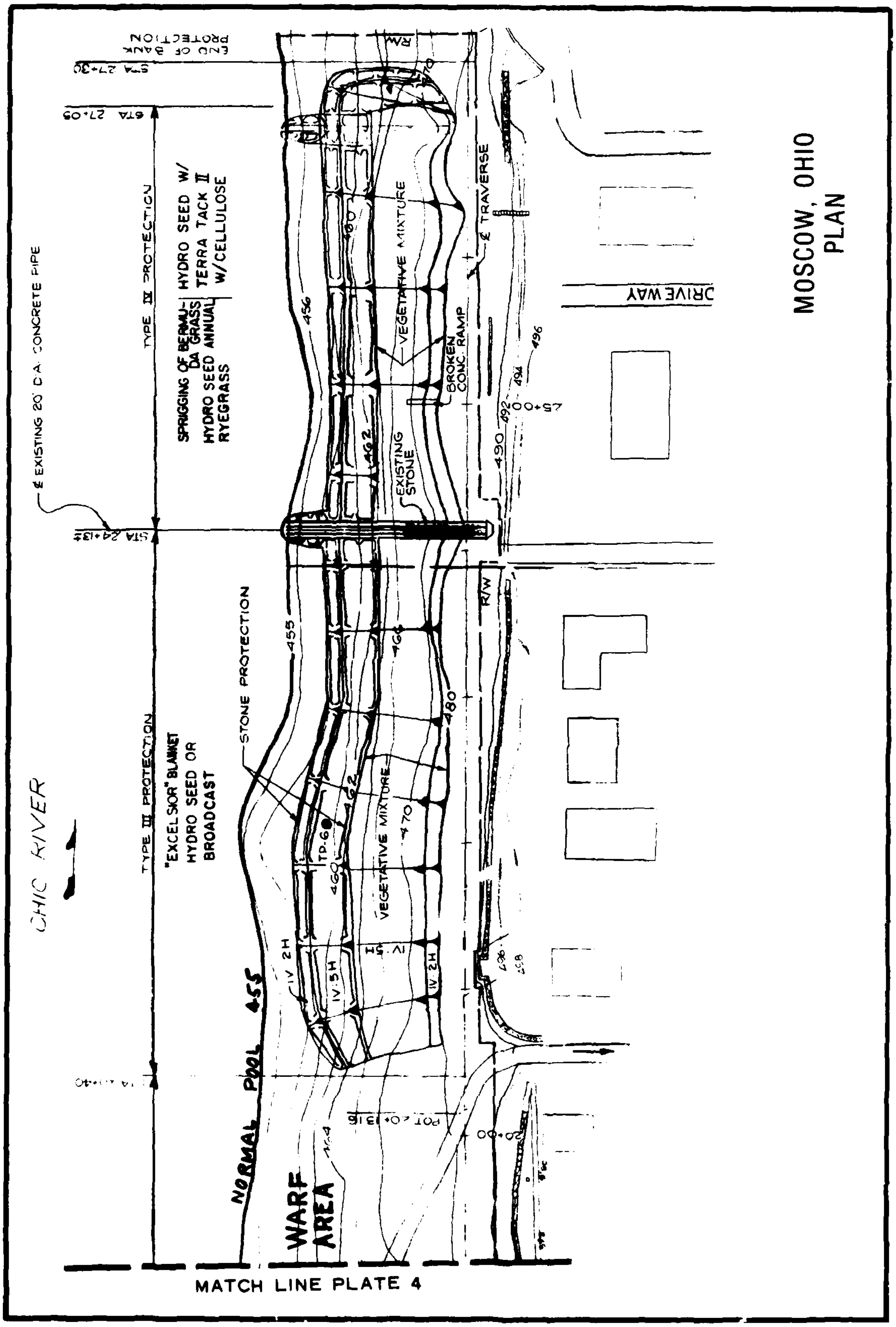

MOSCOW, OHIO
PLAN
MATCH LINE PLATE 4
CHIO RIVER
NORMAL POOL 455
WARF AREA
TYPE III PROTECTION
"EXCELSIOR" BLANKET
HYDRO SEED OR
BROADCAST
STONE PROTECTION
VEGETATIVE MIXTURE
TYPE IV PROTECTION
SPRIGGING OF BERMUDA GRASS
HYDRO SEED ANNUAL RYEGRASS
HYDRO SEED W/
TERRA TACK II
W/CELLULOSE
EXISTING STONE
BROKEN CONC. RAMP
℄ TRAVERSE
DRIVEWAY
℄ EXISTING 20" D.A. CONCRETE PIPE
STA 24+13±
STA 27+05
STA 27+30
END OF BANK PROTECTION
R/W

PLATE 3

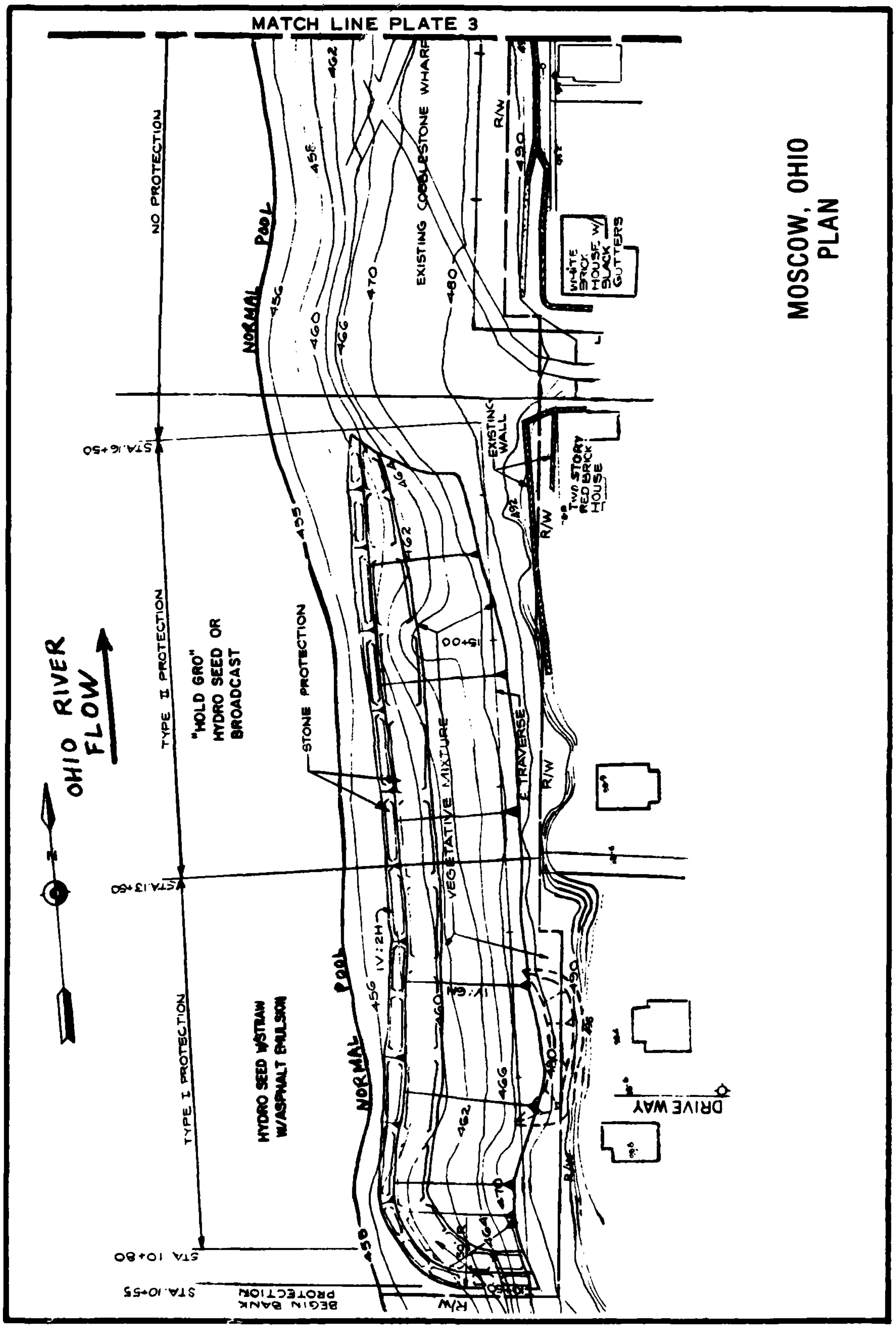
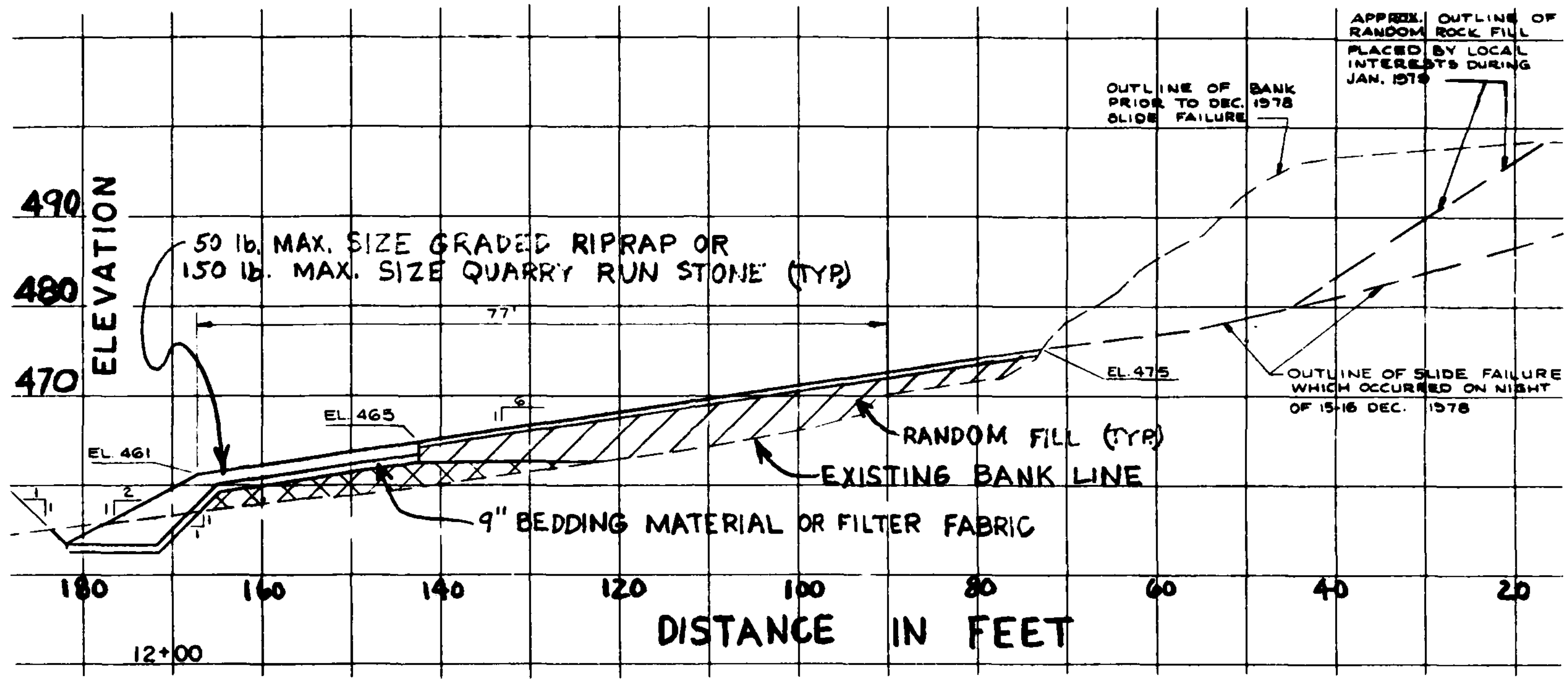

MATCH LINE PLATE 3
MOSCOW, OHIO
PLAN
OHIO RIVER
FLOW
NO PROTECTION
TYPE II PROTECTION
TYPE I PROTECTION
"HOLD GRO"
HYDRO SEED OR
BROADCAST
HYDRO SEED W/STRAW
W/ASPHALT EMULSION
NORMAL POOL
STONE PROTECTION
VEGETATIVE MIXTURE
℄ TRAVERSE
EXISTING COBBLESTONE WHARF
WHITE BRICK HOUSE W/ BLACK GUTTERS
EXISTING WALL
TWO STORY RED BRICK HOUSE
DRIVE WAY
R/W
STA.16+50
STA.13+50
STA.10+80
STA.10+55
BEGIN BANK PROTECTION
15+00
1V:2H
1V:6H
455
456
460
462
464
466
470
480
490

PLATE 4

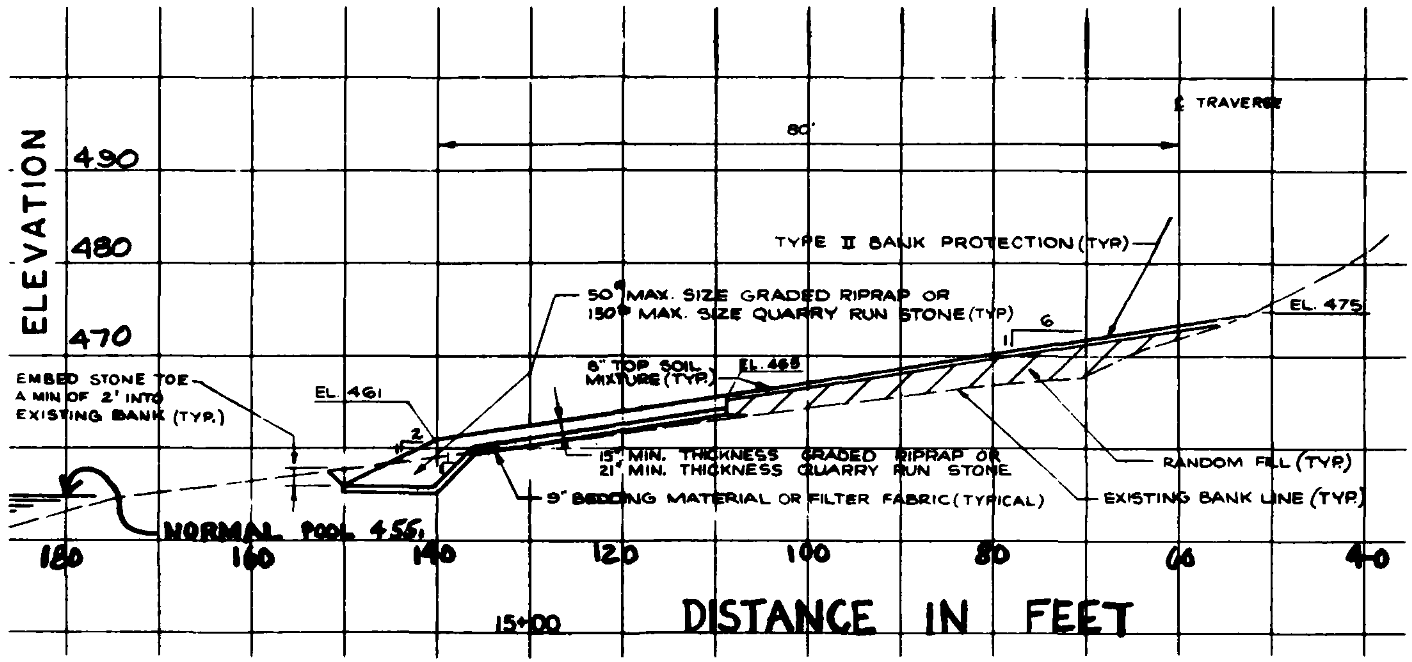


TYPE I PROTECTION HYDRO SEED – STRAW WITH ASPHALT EMULSION

SCALE: 1 INCH = 20 FEET

SECTIONS
STA 12+00

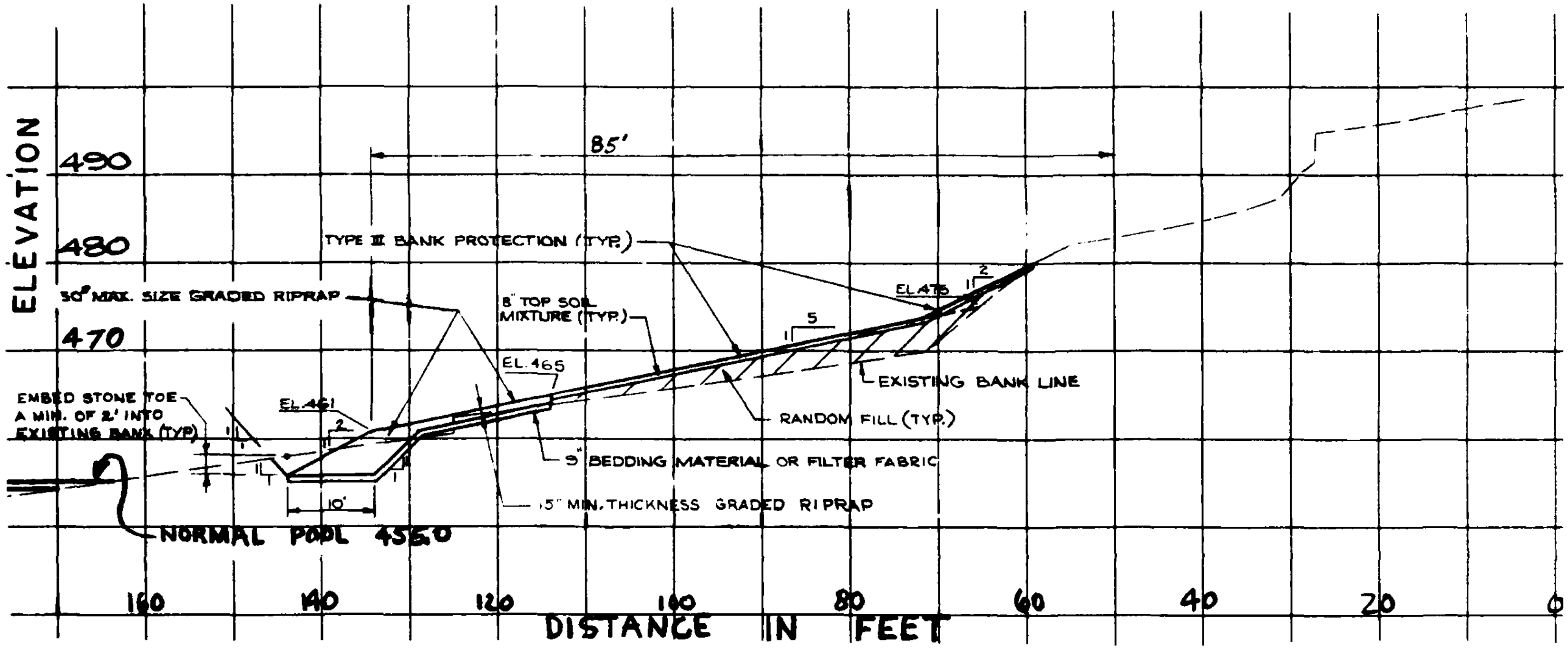
PLATE 5



TYPE II PROTECTION "HOLD GRO", HYDRO SEED
SCALE: 1 INCH = 20 FEET

SECTIONS
STA 15+00

PLATE 6

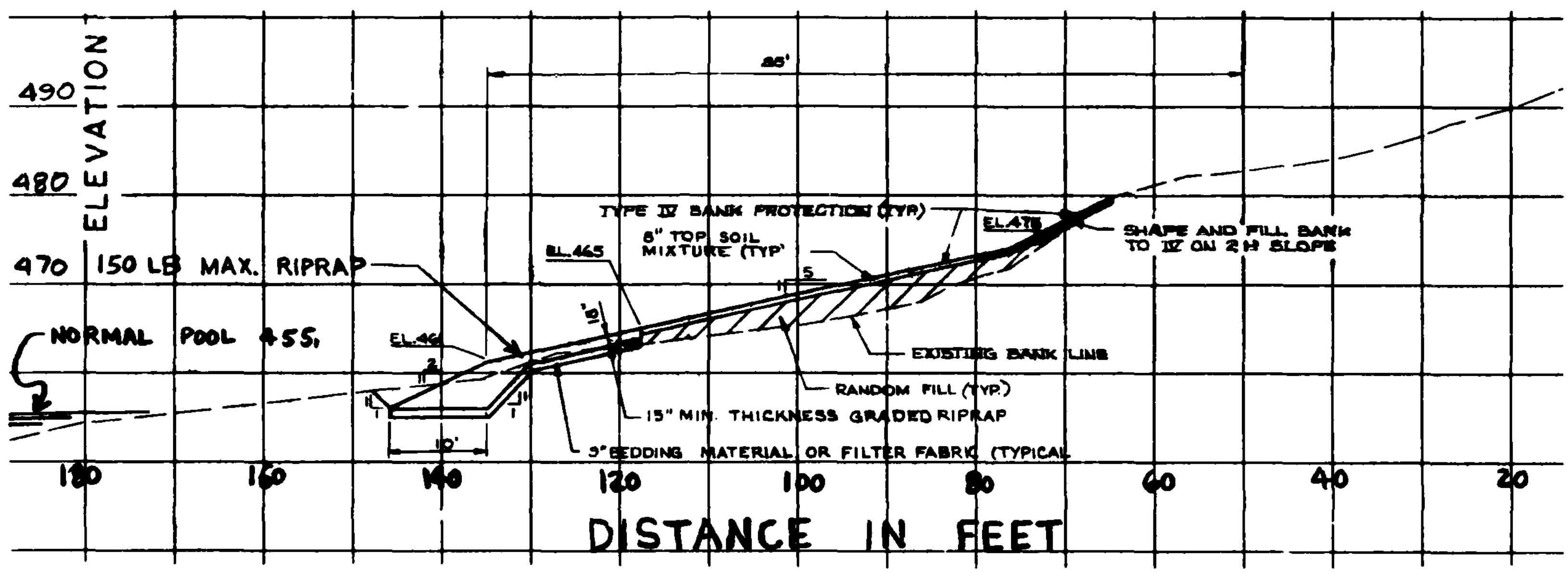


TYPE III PROTECTION EXCESIOR BLANKET, HYDRO SEED

SCALE: 1 INCH = 20 FEET

SECTIONS
STA 23+00

PLATE 7



TYPE IV PROTECTION

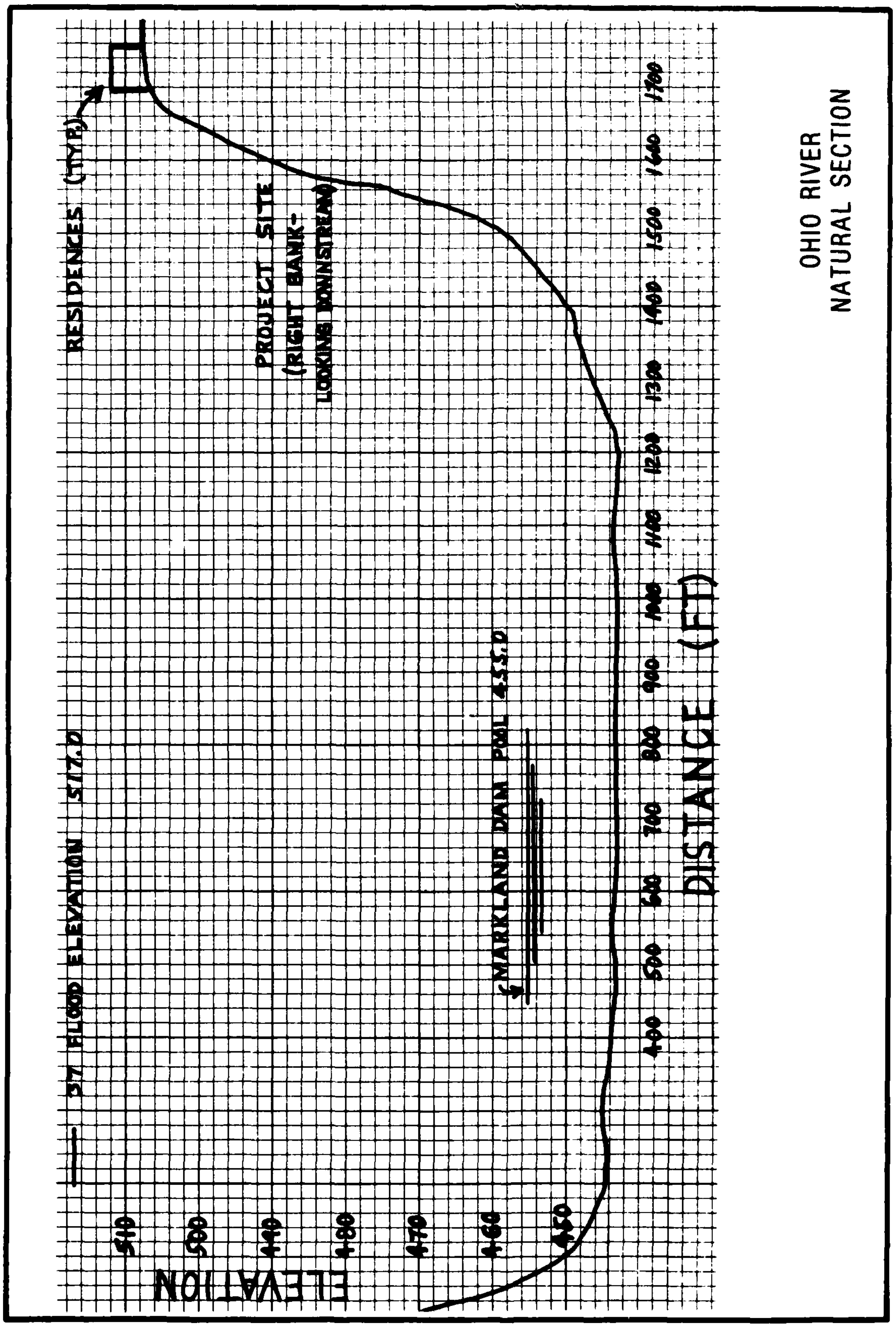
A. SPRIGGING OF BURMUDA GRASS HYDRO SEED ANNUAL RYEGRASS

B. HYDROSEED – TERRA TACK II – CELLULOSE

SCALE: 1 INCH = 20 FEET

SECTIONS
STA 26+00

PLATE 8



OHIO RIVER
NATURAL SECTION

PLATE 9

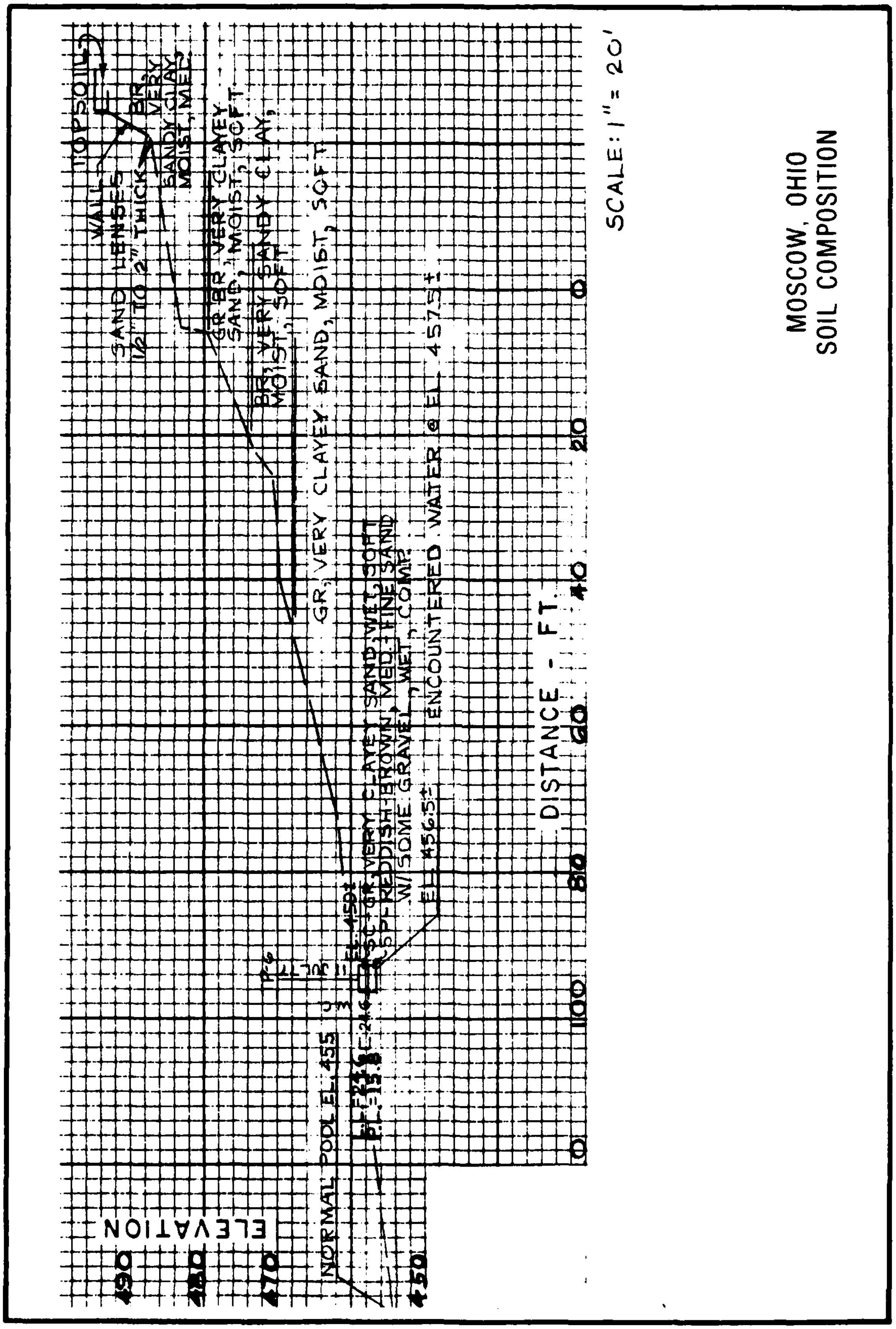
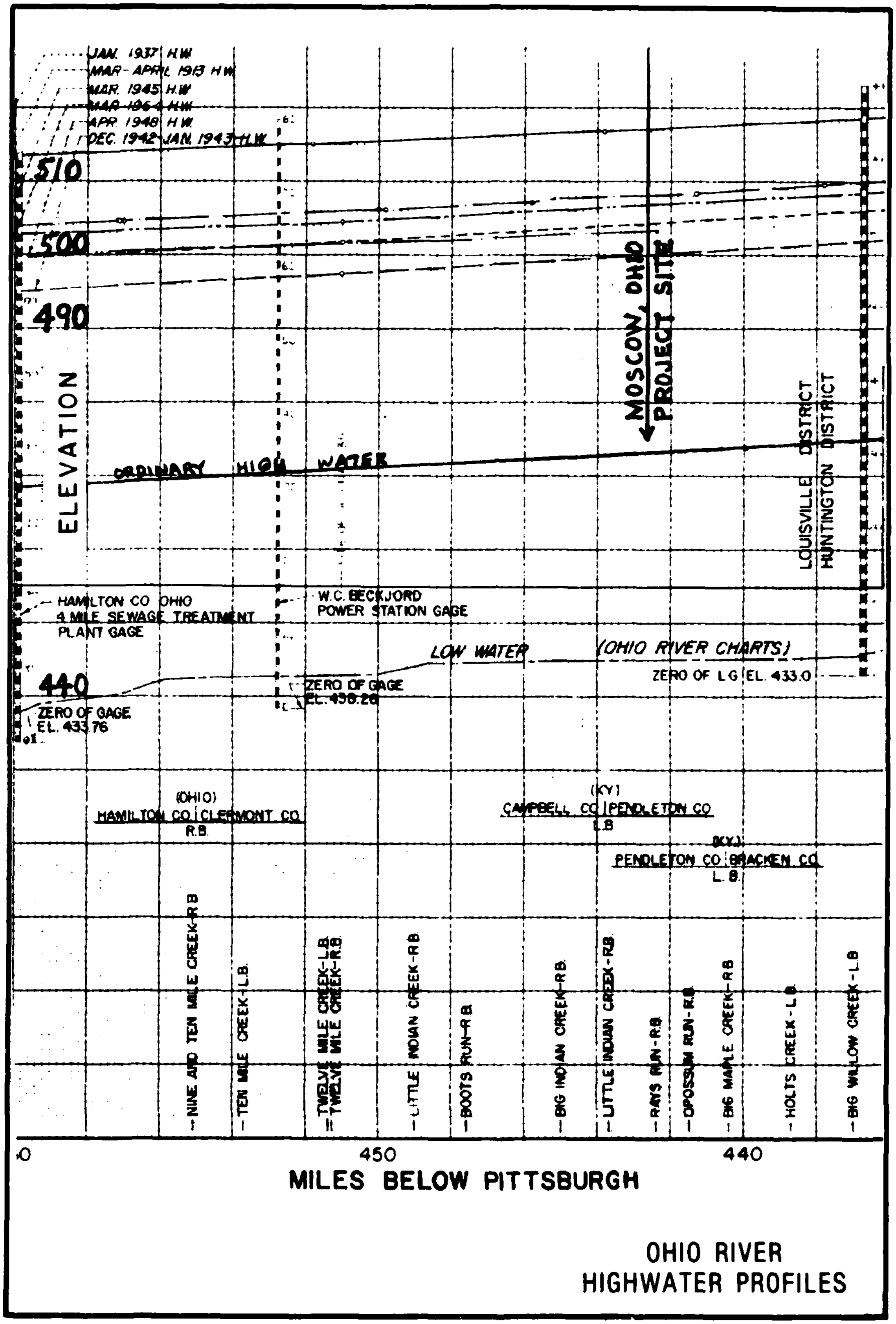
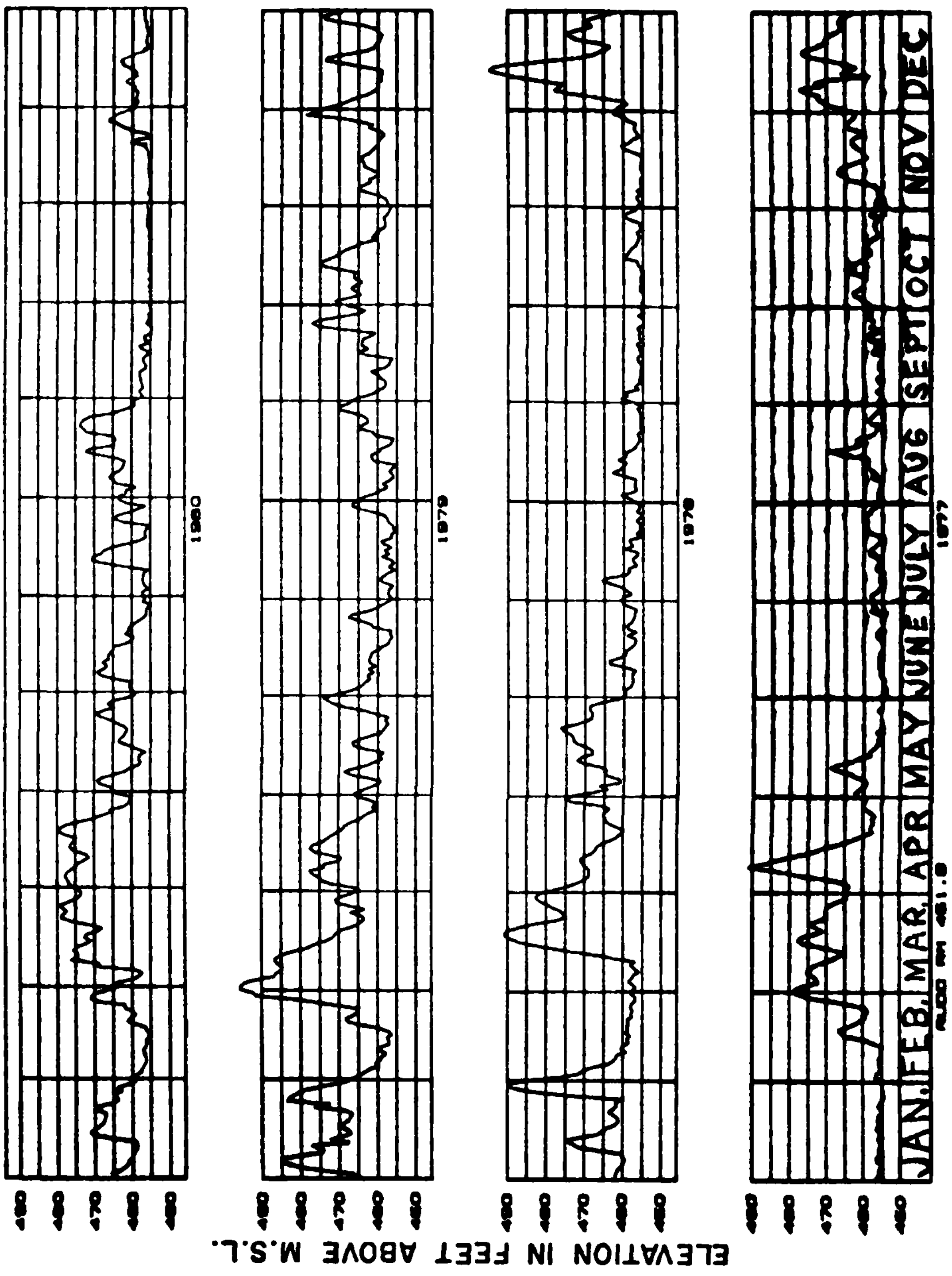

TOPSOIL
WALL
SAND LENSES
1/2" TO 2" THICK
BR. VERY SANDY CLAY, MOIST, MED.
GR. BR. VERY CLAYEY SAND, MOIST, SOFT
BR. VERY SANDY CLAY, MOIST, SOFT
GR. VERY CLAYEY SAND, MOIST, SOFT
ENCOUNTERED WATER @ EL. 457.5±
GR. VERY CLAYEY SAND, WET, SOFT
SP-REDDISH BROWN, MED.-FINE SAND
W/SOME GRAVEL, WET, COMP.
EL. 456.5±
EL. 450±
NORMAL POOL EL. 455
ELEVATION
490
480
470
450
DISTANCE - FT.
0
20
40
60
80
100
0
SCALE: 1" = 20'
MOSCOW, OHIO
SOIL COMPOSITION

PLATE 10



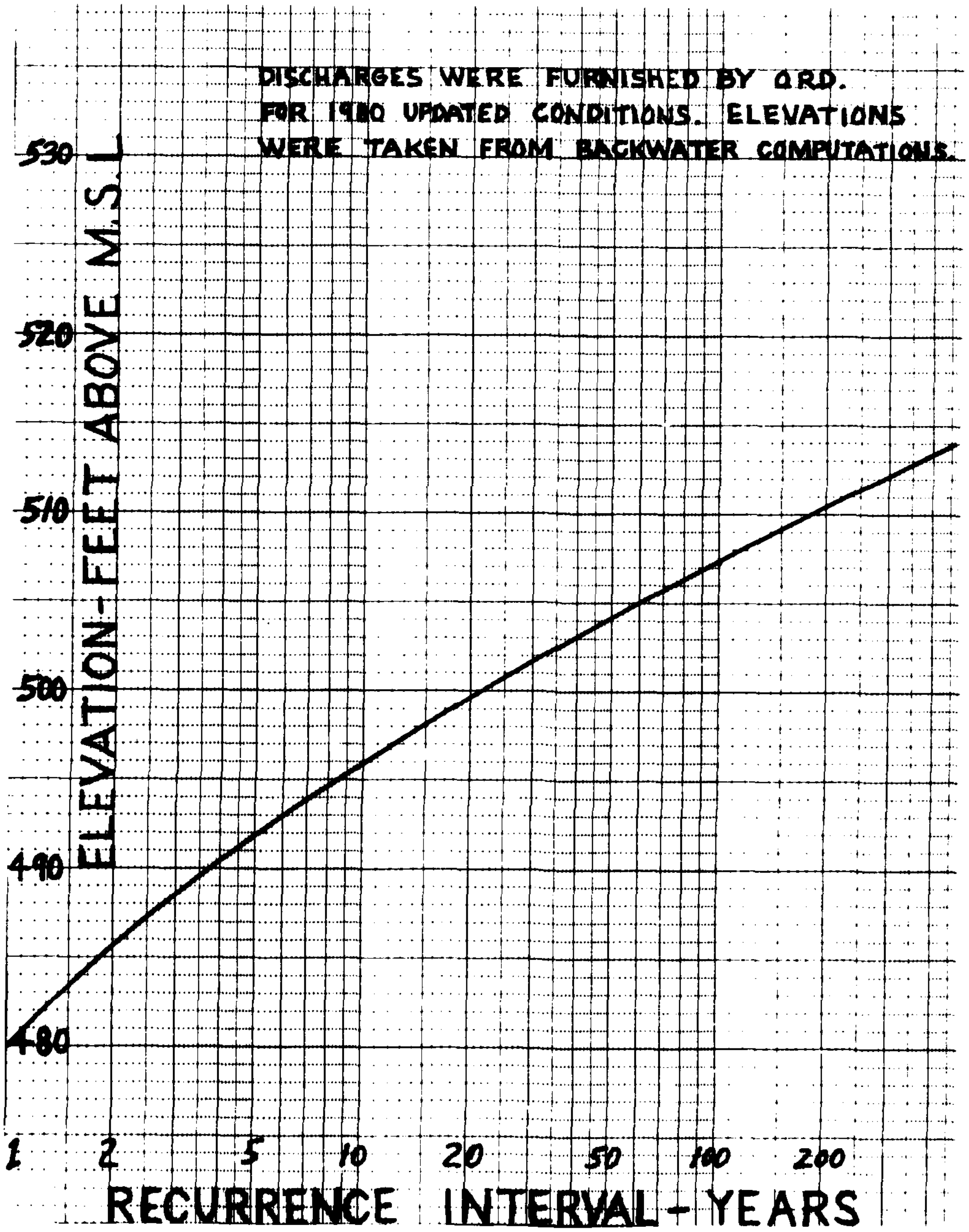
OHIO RIVER
HIGHWATER PROFILES

PLATE 11



OHIO RIVER
HYDROGRAPHS

PLATE 12



OHIO RIVER
ELEVATION FREQUENCY

PLATE 13

OHIO RIVER
MOUNT VERNON, INDIANA

Section 32 Program Streambank Erosion Control
Evaluation and Demonstration Act of 1974

OHIO RIVER AT MOUNT VERNON, INDIANA
DEMONSTRATION PROJECT PERFORMANCE REPORT

I. INTRODUCTION

1. Project Name and Location. Mount Vernon, Indiana Bank Protection, Ohio River, Mile 829. Plate 1 shows a general "Vicinity Map" and site "Location Plan" for the project.

2. Authority. Streambank Erosion Control Evaluation and Demonstration Act of 1974, Section 32, Public Law 93-251.

3. Purpose and Scope. This report describes a bank erosion problem, the types of bank protection used, and a performance evaluation of a demonstration project on the Ohio River constructed and monitored by the Louisville District.

4. Problem Resume. The project is located on the Indiana shore, within the Mt. Vernon city limits at Ohio River Mile 829 (Plate 1). Streambank erosion has been a problem at Mt. Vernon for many years, particularly in the vicinity of the waterworks. The main cause of erosion is the saturation of riverbank soil during high water, resulting in sloughing banks when the river recedes. Once saturated, the much heavier soil becomes unstable after pressure on it from high river water is removed by the receding river. Less important causes of erosion are river currents and eddies. River velocities are normally less than 5 feet per second. Some caving of the banks has been caused by natural drainage through underground porous areas of the soil. In this process, soil is carried out of the ground leaving a hole or cave in the bank which collapses. This process is called "piping." There were various mechanisms of erosion at work in this area, but the saturation and sloughing process is the dominating factor. It is the principal cause of erosion at this project site. Average loss of ground has been 1 foot per year at top of bank.

II. HISTORICAL DESCRIPTION

5. Stream.

a. Topography. The Mount Vernon, Indiana, project is located on the right bank of the Ohio River (Mile 829) in the aggraded valley portion of the Interior Lowland Plateau Province. Mt. Vernon is within the lower one third reach of the Ohio River which forms the southern boundary of the State of Indiana. Along this reach of the river below Cannelton, Indiana, the river flows in a generally southwesterly direction in a meandering channel within a broad aggraded filled valley. Plate 7 is a profile of the river near the project. The tributary streams which enter the river are aggrated along their lower courses accordingly, and flow in wide valleys as tiny channels and everywhere pass soil banks. This is in contrast to the Ohio River and tributaries upstream of Cannelton, Indiana, which flows in channels with deposits generally no deeper than the depth they are capable of scouring to. Although the Ohio River flows in a generally southwesterly direction along its lower one-third reach of the state boundary, it does so in many great nearly right angled turns in alternate westerly and southerly directions. Mt. Vernon is situated at one of these nearly right angle westerly bends in the river course. At Mount Vernon, the Ohio River is approximately 2,000 feet wide. Topography is typical of the flood plain area of the Lower Ohio River Valley with gentle slopes. The valley is characterized by a deep covering of alluvial material over the floor of the valleys of the preglacial drainage. There has been much meandering and lateral movement of the master stream throughout the wide, generally flat area left by the aggradation processes. The river bank of the Ohio River at Mount Vernon is 20-25 feet above the normal pool of the Uniontown Dam. Plate 5 is a typical natural river cross section at the project.

b. Geology. Plate 6 is a natural section at the project with soil types shown. The bedrock consists of shales, sandstones and limestones and coals of the Pennsylvanian System which have been generally non-resistant to the weathering and erosional processes. The regional dip is approximately 25 feet per mile west and northwest. Alluvial deposit depth over bedrock ranges from

65 to 80 feet. At the Mount Vernon project, river banks consist of brown lean to silty clay overlying a gray silty clay at about the normal pool of Uniontown Dam.

c. Locality, Development and Occupation. The Ohio River valley in the vicinity of the demonstration site has developed a diverse industrial character. Over the past several decades, portions of the broad agricultural bottoms have been acquired for industrial development. Mt. Vernon, Indiana, is in the Uniontown Dam pool. Uniontown Dam is at Mile 846. Within the Uniontown pool, the valley contains several large cities and towns along its banks. Mount Vernon, the county seat, is in Posey County and has a population of around 10,000. Evansville, Indiana, is the largest city; other large cities near the area are Newburgh, Indiana; Uniontown, Kentucky; and Henderson, Kentucky. These cities have a varied industrial makeup from large nationally known manufacturing companies to many small manufacturing and service companies. Babcock & Wilcox and General Electric companies have large plants in Mount Vernon.

The most common occupation in the area is farming with corn and soybeans the principal crops. Hogs are also raised by many.

d. Hydrologic Characteristics. Mt. Vernon, Indiana is situated on the outside of an Ohio River bend at River Mile 829. Mt. Vernon is characterized topographically by a high bank 25-30 feet above Uniontown Dam's normal pool elevation 342. Drainage area of the river at the project site is 107,700 square miles. Slope of the river averages about 1 foot per mile and is .5 foot per mile at the site.

The project site is 17 miles upstream from Uniontown Locks and Dam. Top of bank at the site is about elevation 370. The river is approximately 2,000 feet wide at the site. Velocities range from about 1 foot per second at normal pool to roughly 5 feet per second during flooding. Ordinary High Water (OHW), 100-year flood, and record 1937 flood elevations at the site are 348.5, 372.0 and 378.0. Temperatures in the area are generally moderate, rarely above 100^{o}F and rarely below 0^{o}. Ice problems are not normally encountered at the project site. Design of bank protection to withstand ice forces was

therefore not considered. Elevation hydrographs for the Uniontown pool (years 1977 through 1980) are shown on Plate 8. Plate 9 is an Ohio River elevation versus frequency curve for the area. Plate 5 is a natural river cross section at the site. Plate 7 is an Ohio River profile with historical flood profiles, channel bottom and tributaries in the area.

e. Channel Characteristics. Channel characteristics are discussed in paragraph d above.

The Ohio River has been an important artery since prehistory and has undergone navigation improvements since 1824 when Congress provided for removal of obstructions such as bars and snags. For many years river navigation was facilitated solely by open channel improvements. In addition to removal of channel obstructions, stone training dikes were constructed at various bars in order to constrict the channel and increase the scour of the river. The first movable dam on the Ohio River was located at Davis Island, 4.7 miles below Pittsburgh, and opened to commerce October 7, 1885. A system of locks and movable dams was eventually constructed along the entire Ohio River. These early dams incorporated a navigable pass to provide a channel for open river navigation during periods of high flow. A series of wickets, heavy timber shutters, were raised to impound water as needed to maintain a navigation pool. When not required, the wickets would lie flat at such a depth as to offer no obstruction to free navigation through the pass. Replacement of these original navigation dams with fixed, gated structures having higher lifts has been ongoing. Uniontown Dam was placed in operation in 1975. Uniontown Dam (normal pool 342.0) replaced old Lock and Dam 49 (normal pool 331.0).

f. Environmental Considerations. The general aspect of the vegetation from the shoreline to top of bank is bare or willow thicket, willow to black locust thicket, and at the higher elevation, more open areas of grasses and herbaceous plants. The area is in a fairly early stage of succession to riparian forest. Few of the existing trees exceed 4 inches in diameter and many of the nonwoody species are invasive species. A list of plants identified on the site include: black willow, silver maple, cottonwood, black locust and box elder trees and various weeds and grasses.

The fauna of the site were noted to be sparse and not particularly notable or diverse. The condition of the habitat and its proximity to an urban area indicates that it would be of little value to rare, endangered or threatened species of terrestrial wildlife.

The aquatic life in the immediate proximity of the project was not examined. However, the predominant fish species present in this general section of the river include gizzard shad, freshwater drum, emerald shiner, blue catfish, channel catfish and threadfin shad.

An investigation of cultural resources on the site uncovered no structures that would be affected.

The proposed project will exert short term adverse impacts on water quality during project construction as a result of increased turbidity. The long term impact on water quality should be positive as a result of decreased susceptibility of the bank to massive failure and erosion which will lessen localized river turbidity.

The impact on the natural vegetation and fauna will be minimal and of a short term nature. A section of the project area will be stabilized by regrading and planting of willow and fescue which closely corresponds to the existing vegetative cover. Whenever possible, the existing vegetation will be retained. So, although there will be some disruption of plant and animal populations during construction, the area should quickly recover. The long term stability to be provided by the project should enhance the area from the standpoint of providing stabilized habitat conditions for wildlife populations.

6. Demonstration Site--Test Reach.

a. Hydrologic Characteristics. The hydrologic characteristics are as previously stated in paragraph 5-d.

b. Hydraulic Characteristics. Hydraulic characteristics are also discussed in paragraph 5-d.

c. Riverbank Description. Plate 6 is a natural section at the site with delineations of soil types shown. A test boring was used to make this plate. Since completion of the project vegetation has increased considerably--see photographs. The "no work" areas are becoming more stable with time because of increasing vegetation. Vegetation is growing in riprap areas and has covered almost 100 percent of the area of rock covered by wire mesh.

III. DESIGN AND CONSTRUCTION

7. General. The relatively long bank to be protected (1250 feet+) gave an opportunity to experiment with various types of bank protection, including an area of no protection other than natural vegetation. Plate 3, Plan, shows the different types of protection used. The various types were "no work;" sand-cement filled paper bags, riprap, fabriform and smaller rock secured by wire mat. Photographs also show the various protection schemes.

8. Basis for Design. The design of protection was based on the hydraulic aspects of the Ohio River, a large, wide river of moderate depth which during high flows places considerable forces on its banks. Velocities can reach 5 to 6 feet per second. Commercial tow traffic waves and natural waves reach 2 feet in height. Eddies and currents can weaken protection if it is not designed to withstand them. The designs were intentionally marginal for the purpose of experimentation. These are discussed in subsequent paragraphs.

9. Construction Details. The protection schemes are shown on Plate 3, a plan. Also Plate 4 shows typical cross sections for the wire mat segment, sand-cement bag segment and the fabriform segment. For these areas the ground slopes were prepared and then protections were placed. No work was done in the areas of no protection. It was hoped that these areas would eventually stabilize since protection would be placed nearby. Heavy machines, trucks and dozers were assisted by laborers on foot to assure exact placement of protection. See photograph 3 which shows placement of wire mats. The upstream limit of the project is at the Short Milling Company with a combination of riprap integrated with existing willows for a 220-foot reach. This is

followed by a 270-foot reach of paved wharf for which no work was required. The following reach, about 260 feet long, primarily for protection of the water works, has a riprapped toe. The portion of the bank above the toe was protected by nylon reinforced paper bags filled with a sand-cement mixture for about 150 feet and by fabriform for about 110 feet. Fabriform consists of nylon mattresses filled with grout. The bank slope in this reach was about 1.5H:1V/.

The remaining 440 feet of project is primarily to protect the eroding natural toe at the base of a railroad embankment. About 100 feet was partially covered by willows and was left undisturbed. The next 1,000 feet of bank had its eroded toe protected by a riprap dike. The final 200 feet of the project had the eroding toe protected by stone bedding material up to 4 inches in size secured by wire mats. The total length of the project is about 1,250 feet, including areas requiring no protection. Plate 4 shows cross sections of the originally constructed project. The side slopes of the natural toe at the base of the railroad embankment is about 4H:1V.

The project was begun in September 1976 and completed in February 1977.

10. Cost. Total cost of the project was $108,000 including Engineering and Design and Supervision and Administration. Actual construction cost for each scheme is shown in the table below. Total cost including supervision, administration, engineering, design and construction is also given.

Scheme	Construction Cost/Square Foot	Construction Cost/Linear Foot	Total Cost/Linear Foot
"no work"	0	0	0
Stone only	$1.11	$ 55.	$ 87.00
Wire mat over stone	1.74	55.	87.00
Sand-cement filled bags	1.89	95.	126.00
Fabriform	3.33	167.	198.00

IV. PERFORMANCE OF PROTECTION

11. Monitoring Program. Visual observations were made about four times per year, with additional visits to the site following periods of protection failures and repair or reconstruction of the protection. Plate 2 shows the parameters monitored and the frequency. Analysis of environmental and geotechnical aspects of the project area were made on a one time basis. These are in Para. 5f in this report. Ground level photography was made during each visual observation. Wave height was measured on a staff gage at the upstream limit of the project. Pool levels were obtained from a U.S. Weather Service gage at Mt. Vernon. A velocity instrument was not used since stream velocity is not considered important in this case. Current velocities were relatively low and were estimated by engineers during inspections. The monitoring program has been completed for this project.

12. Evaluation of Protection Performance. Shortly after completion of the project two significant river rises occurred which caused shifting of many of the cement bags--see photographs. By May 1977 it appeared that a major repair of the cement bags area would be required. Heavy runoff from a 2-inch rain storm had aggrevated the slippage problem. Loss of bedding material under the bags was apparently a major cause of their failure. During October 1977 the cement bag area was repaired by adding a catch basin and pipe to handle the runoff problem and by placing stone over the damaged area. A sketch of this repair plan is shown on Plate 3. Photo 7 shows the area, just after repair. By June 1978 some additional slippage of the cement bags was occurring. Also some erosion in the "no work" areas was occurring. By May 1979 continued serious slippage of the cement bags was taking place. A major repair would be required there. The wire mat, fabriform, and riprap areas meanwhile, had held up very well. No appreciative problems were evident in these areas.

13. Rehabilitation. In November 1979, an 18-inch thickness of 150-pound maximum weight quarry-run stone was used to make final repairs to the project. The entire area of cement bags (Stations 13+00 to 14+50) was covered with stone. Stone was placed at the downstream side of the fabriform in a no work area. A stone dike was placed from Stations 15+61 to 16+77 to

help stabilize the previously unprotected area. Two damaged wire mats were also replaced. Photo 9 shows the project after rehabilitation. Plate 3 shows locations where final repairs were made. The 15 July 1980 inspection showed the entire project to be stable and performing well. "No work" areas were covered with heavy vegetation of various types. Vegetation was also heavy in the wire mats. No additional repairs are expected. Total cost including rehabilitation was $207,322. The project is scheduled to be turned over to the locals sometime during 1981.

14. Summary of Findings. Analysis of all information regarding the project brings forth the following conclusions:

a. Use of sand-cement filled bags placed edge to edge should be limited to areas of slopes equal to or flatter than 2.5 horizontal to 1 vertical due to tendency to slide. Otherwise, bags should be layed horizontal and overlapped to form the steeper slope. By using burlap bags instead of paper, there would be more bonding between bags. Also, sand-cement bags should be used with little or no bedding material as excessive bedding material is easily lost during high water periods. This method appears vulnerable to ice damage. A rare ice jam in 1978 may have dislodged several bags, weakening the surrounding area. River ice is of such rarity in this area that design to protect against ice damage is not warranted and was not done.

b. Fabriform is an extremely stable protection even on slopes as steep as 1 vertical to 1 horizontal. Because of its relative high cost, its use is not warranted unless a steep slope is unavoidable and stability of protection is essential.

c. The upstream and downstream ends of fabriform should be keyed into bank; or stone added, as recommended by manufacturer, since these areas, if unprotected may create localized currents and eddies causing erosion of bedding material from edges of fabriform. See photograph 6.

d. Vegetation growth on or through fabriform is not likely.

e. Stone covered with wire mats does a good job of bank protection and allows heavy regrowth of vegetation. This method is more expensive than placing standard stone protection. Also, the project life of this method is limited to life of the wire. Eventually the wire will rust or in some cases can be subjected to damage. The vegetation growth through the rock and mats could stabilize the bank for many years after wire mats have rusted away.

f. Areas of "no protection" between protected areas were left unprotected when willows below normal pool died. Normal pool had recently been raised with completion of Uniontown Dam, 17 miles downstream. The upstream "no protection" area (Station 9+00 to 9+70) has sufficient growth above normal pool to remain stable. Willows appeared to offer satisfactory protection here.

g. Areas immediately upstream or downstream of a protection project may erode. Care should be taken in initial installation of protection to make a smooth transition to natural areas so that localized currents or eddies are not created there.

h. The most economical form of protection used, considering initial installation and maintenance costs, is "quarry run" stone. It has stabilized on a steep slope (1.5H to 1V). It allows some regrowth of vegetation and can resist the low to moderate velocities of the lower Ohio River.

i. An important conclusion from the Mt. Vernon project is that areas of "no protection" may remain stable if there are moderate slopes (flatter than 2.5H:1V) and dense vegetation growth. This is especially true if transitions are smooth and flood duration is not so excessive as to significantly limit vegetative growth.

PHOTO NO. 1. Feb. 77. Project just completed. Looking downstream at sand cement bag area with riprap tow, Stations 12+50-13+50±.

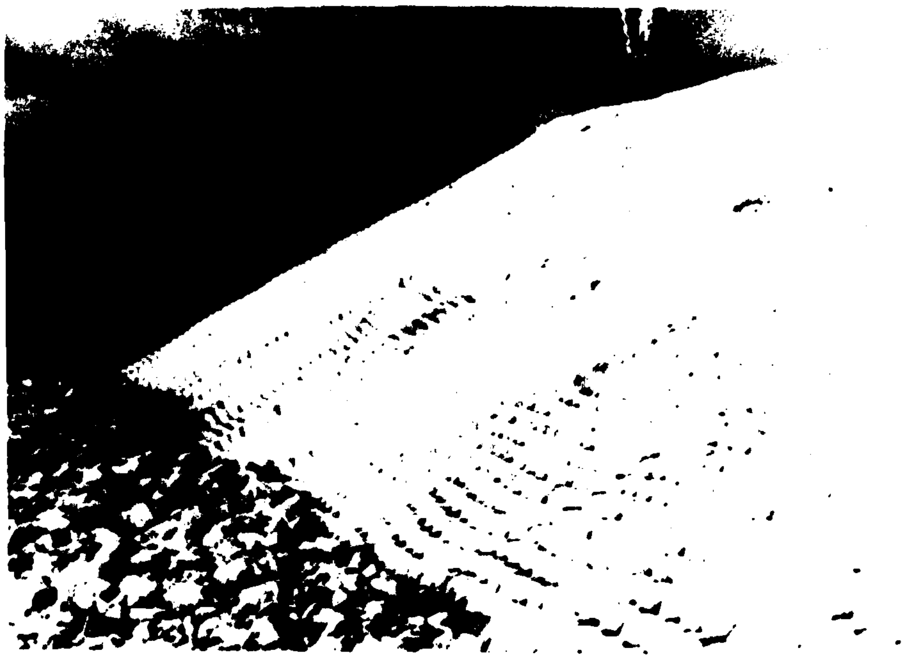


PHOTO NO. 2. Feb. 77. Project just completed. Looking downstream at fabriform area with riprap toe, Stations 14+50-16+00.

PHOTOS 1 AND 2

PHOTO NO. 3. Feb. 77. Project just completed. Looking downstream at wire covered rock, Stations 18+00-20+00.

PHOTO NO. 4. Feb. 77. Project just completed. Looking upstream at riprap area (Stations 8+50-9+20). Note unprotected areas upstream and downstream of protected areas.

PHOTOS 3 AND 4

PHOTO NO. 5. May 77. Slippage of cement filled paper bags, Stations 13+50-14+00.

PHOTO NO. 6. May 77. Erosion just downstream of fabriform in "no-work" area (Stations 15+60-16+00). This area was later protected by rock placement.

PHOTOS 5 AND 6

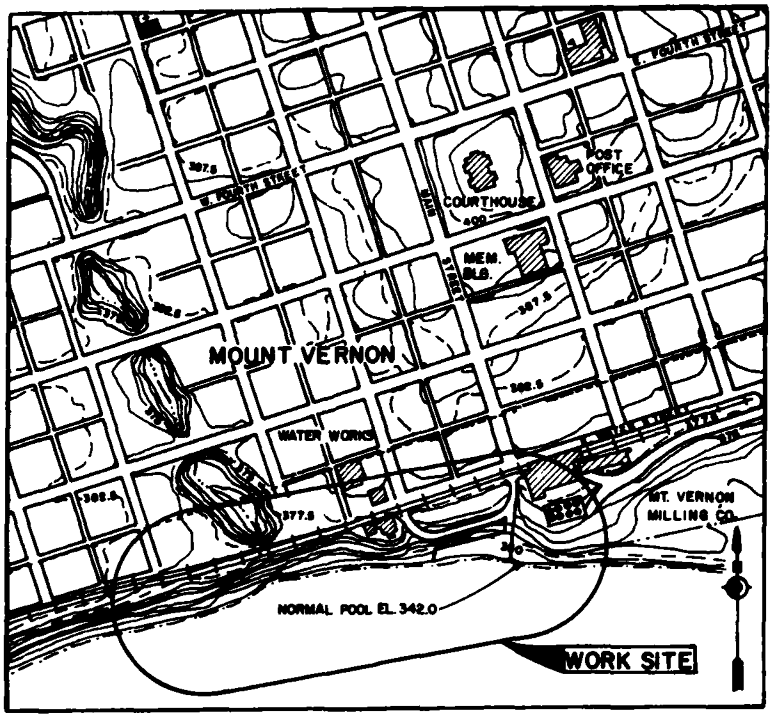
PHOTO NO. 7. Oct. 77. Remedial repair of cement bag area by rock and pipe (under rock). Plate shows details of remedial repair.

PHOTO NO. 8. May 79. Continued loss of cement bags due to loss of bedding material and sliding during high water. Rehabilitation obviously needed at that time.

PHOTOS 7 AND 8

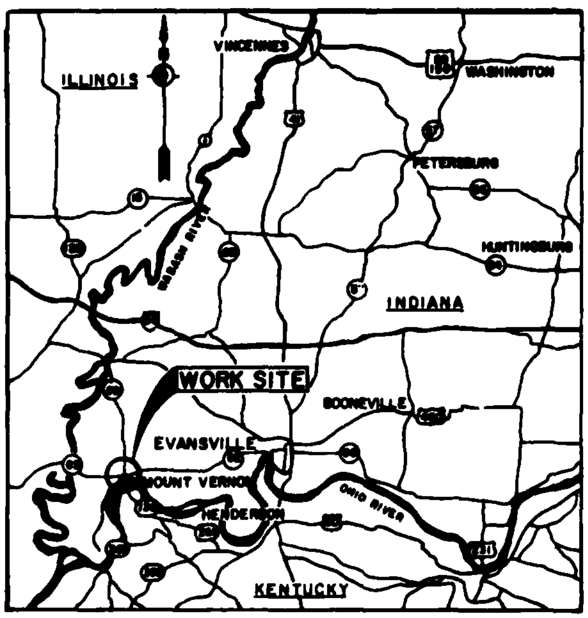
PHOTO NO. 9. July 1980. Looking downstream at project following major rehabilitation of project. Note significant growth of vegetation, Stations 12+00-20+00.

PHOTO 9



LOCATION PLAN

SCALE IN FEET
300 0 300 600 900 1200



VICINITY MAP

SCALE: 1" = APR 11.6 MILES

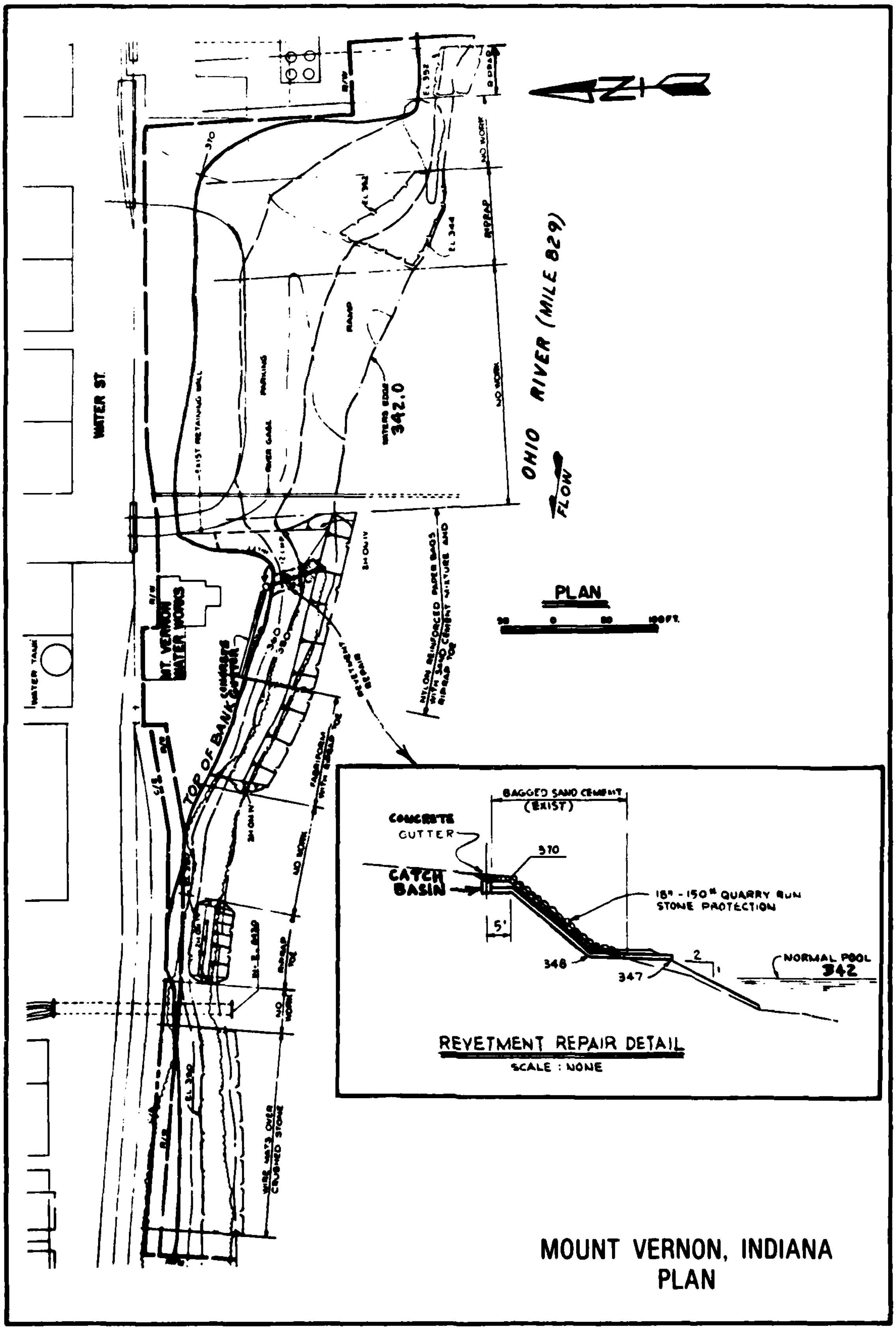
MOUNT VERNON, INDIANA
LOCATION MAP
AND
VICINITY MAP

PLATE 1

Parameter	Item	Frequency
Geometry	1. Overbank cross sections thru various types of protection used. See Plate 4.	Once-signif. changes to be resurveyed.
	2. Full channel cross sections.	Once
	3. Ground photos from fixed reference points.	Quarterly
Climate	1. Air temperature, precipitation, wind.	Continuous
	2. Ice conditions, snow cover noted from visual observations.	As available
Hydraulics	1. River stage record (weather service gage at Mount Vernon).	Daily
	2. Stream velocity (estimated from observation).	Quarterly
	3. Wave height (fixed staff gage).	Quarterly
	4. Other miscellaneous river conditions: current direction, turbidity, etc.	Quarterly
Streambank Protection	1. Monitor dimensional changes of marked structural and vegetal units through photos and manual measurement.	Quarterly
	2. Observe durability of marked units of structural material (qualitative).	Quarterly
	3. Observe condition of marked plants.	Quarterly
	4. Record initiation and measure progression of failures in bank protection.	Quarterly
Geology and Soils	1. Materials properties testing.	Once

MOUNT VERNON, INDIANA
DATA COLLECTION TABLE

PLATE 2



MOUNT VERNON, INDIANA
PLAN

PLATE 3

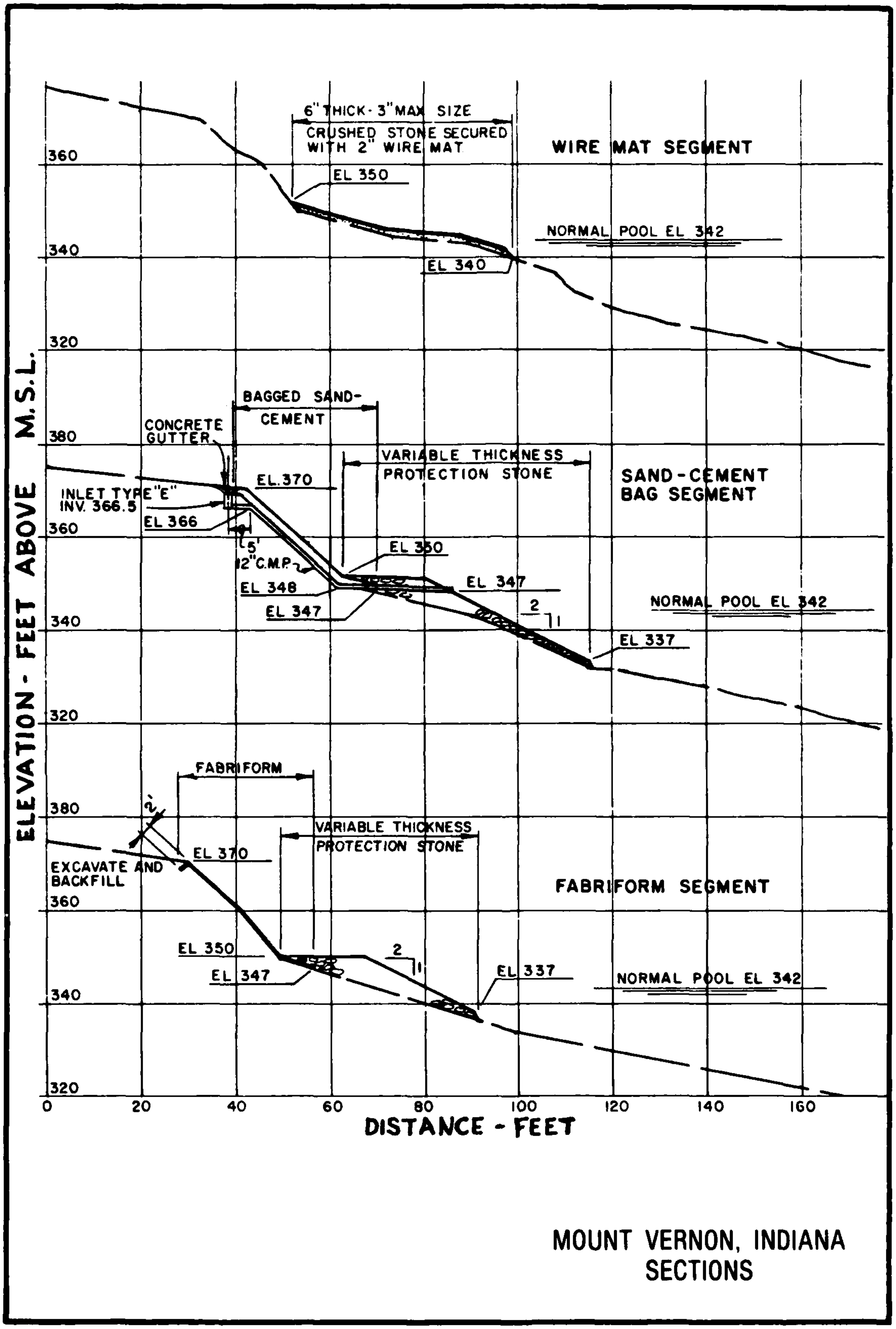
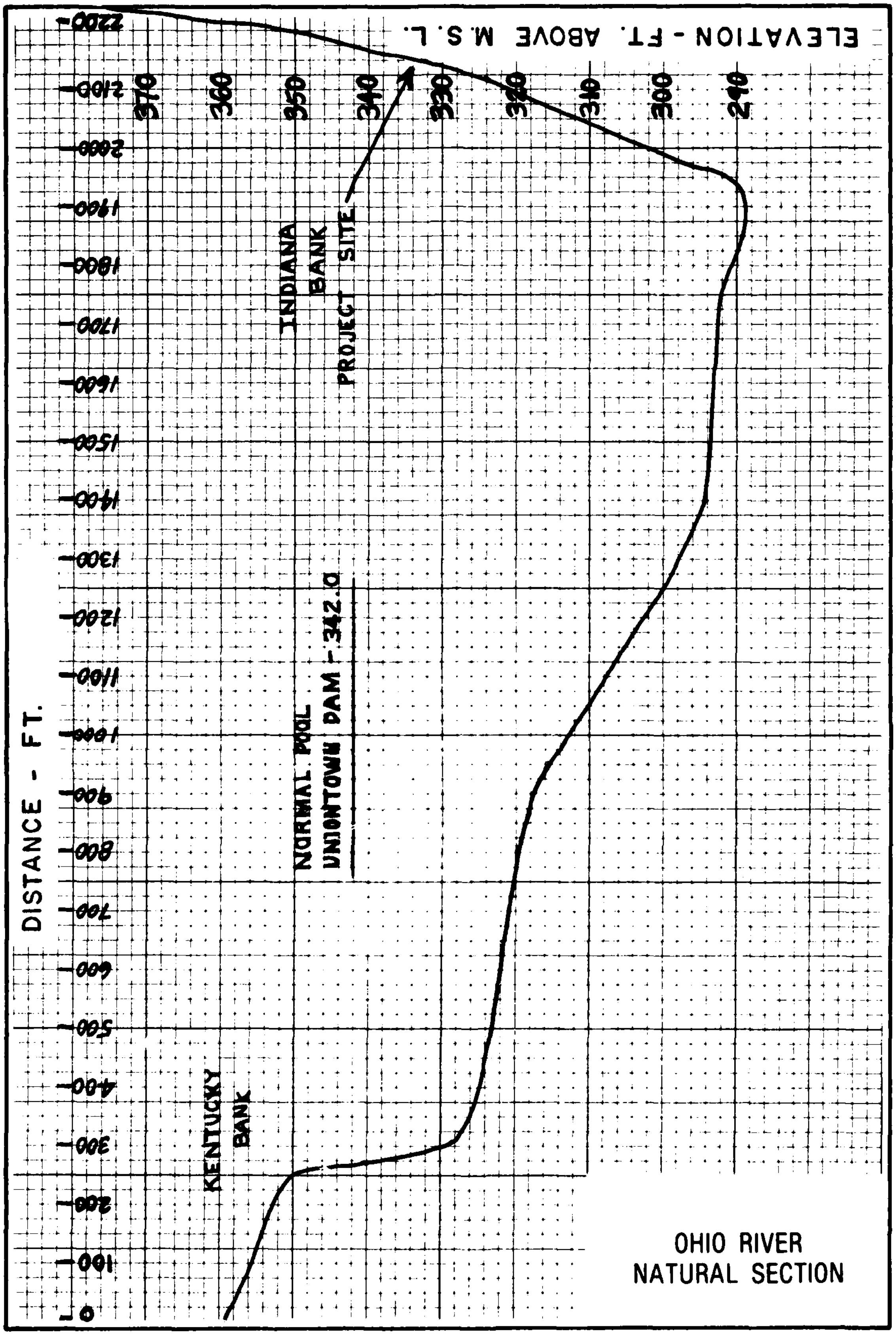
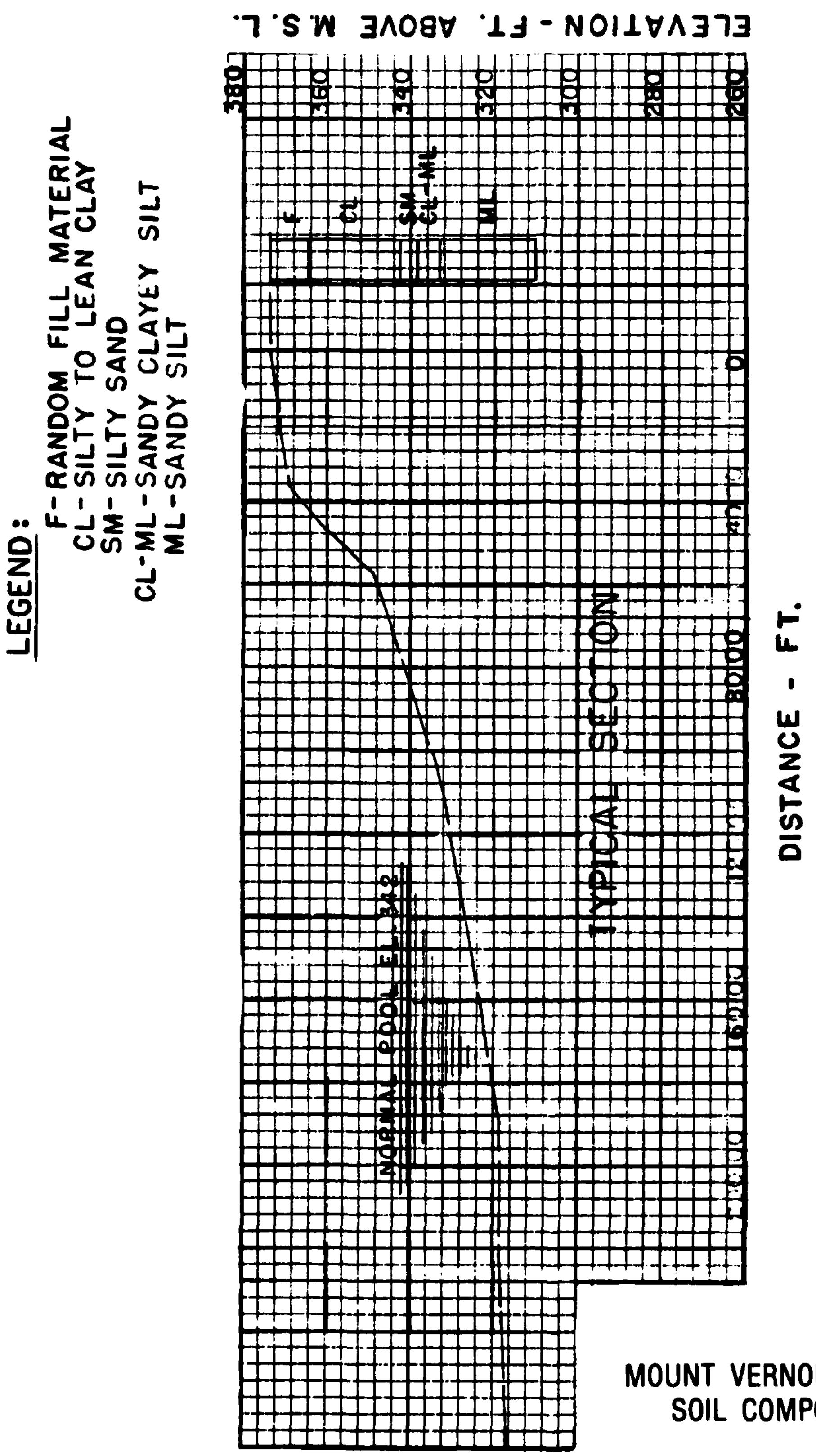

6" THICK - 3" MAX SIZE
CRUSHED STONE SECURED WITH 2" WIRE MAT
WIRE MAT SEGMENT
EL 350
NORMAL POOL EL 342
EL 340
BAGGED SAND-CEMENT
CONCRETE GUTTER
VARIABLE THICKNESS PROTECTION STONE
EL.370
SAND-CEMENT BAG SEGMENT
INLET TYPE "E" INV. 366.5
EL 366
5'
12" C.M.P.
EL 350
EL 348
EL 347
EL 347
NORMAL POOL EL 342
EL 337
FABRIFORM
2'
EL 370
VARIABLE THICKNESS PROTECTION STONE
EXCAVATE AND BACKFILL
FABRIFORM SEGMENT
EL 350
EL 347
EL 337
NORMAL POOL EL 342
ELEVATION - FEET ABOVE M.S.L.
DISTANCE - FEET
MOUNT VERNON, INDIANA
SECTIONS

PLATE 4



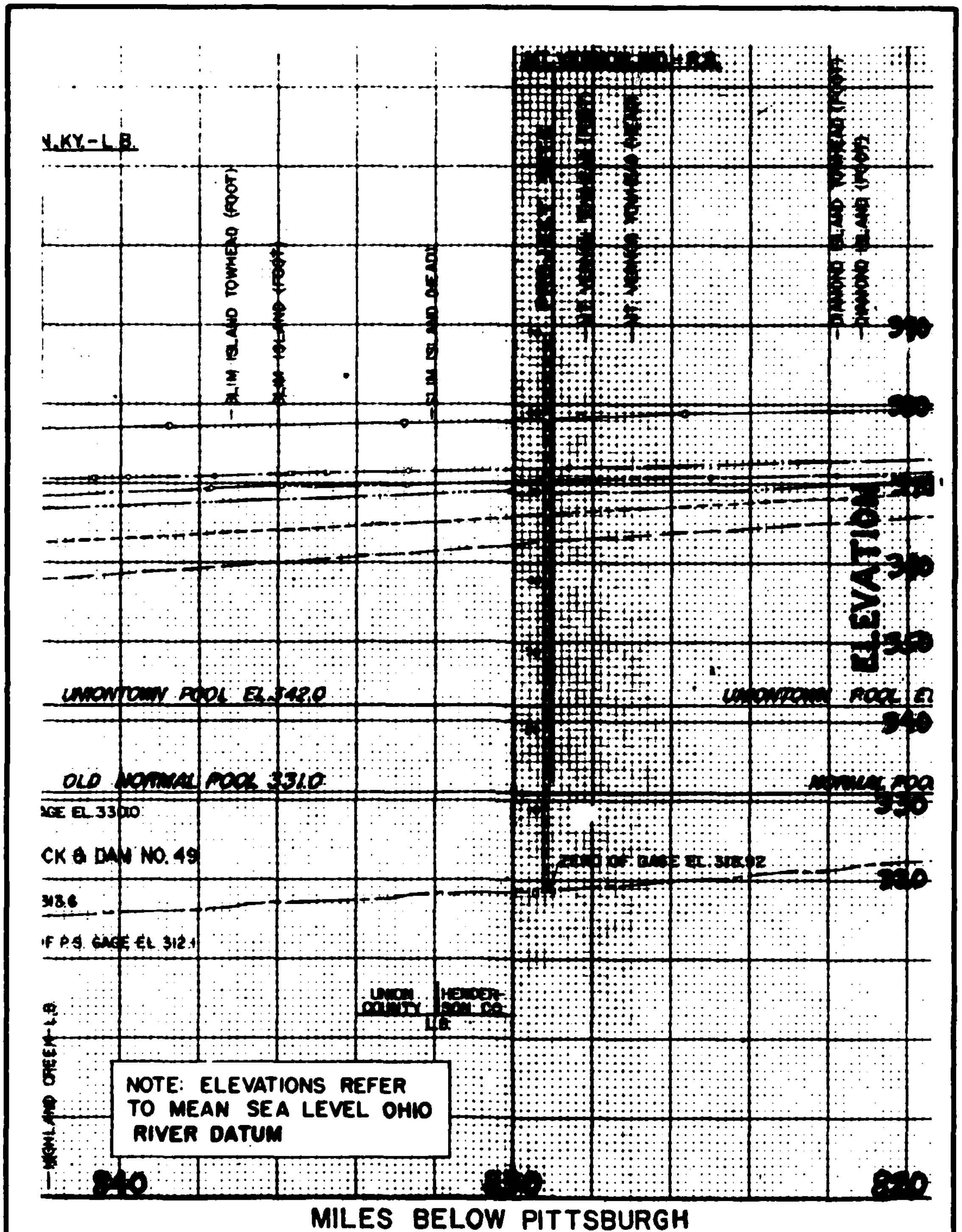
OHIO RIVER
NATURAL SECTION

PLATE 5



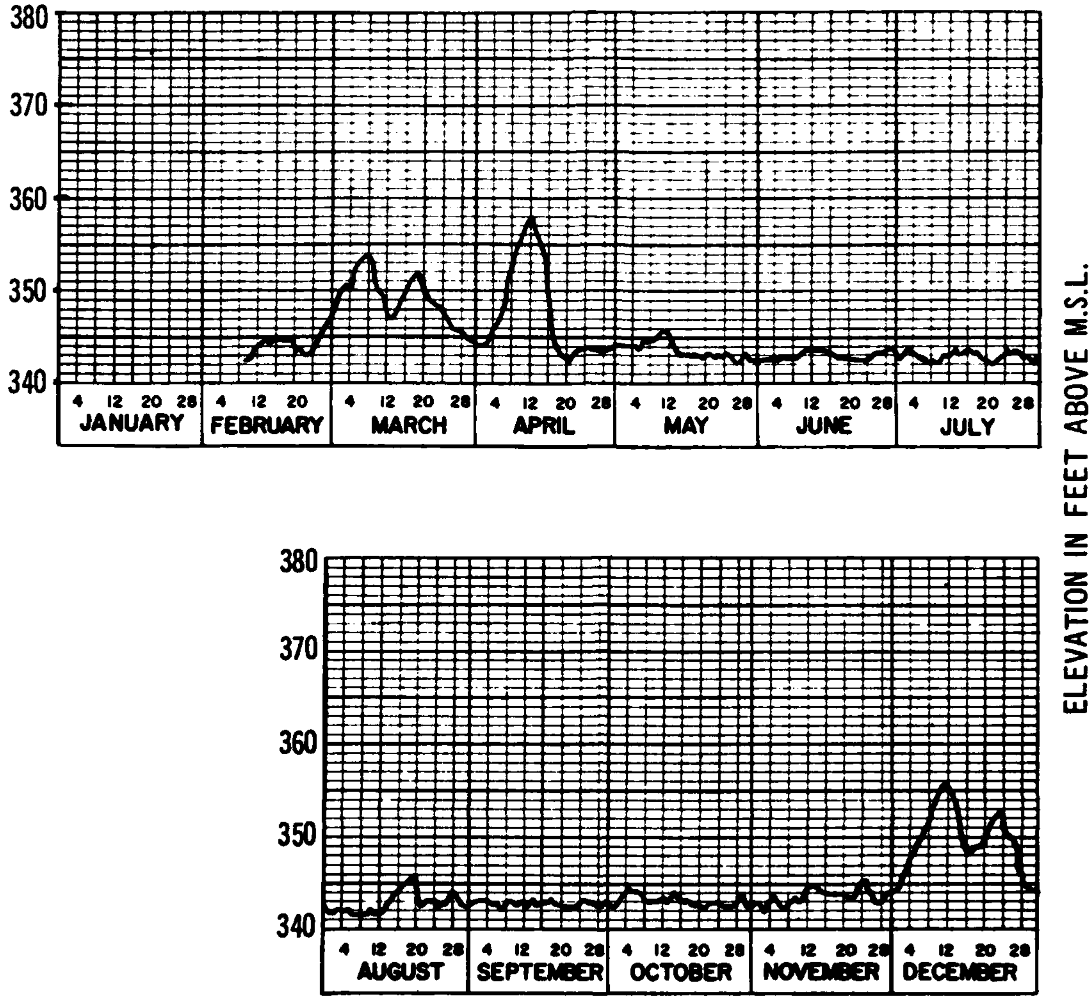
MOUNT VERNON, INDIANA
SOIL COMPOSITION

PLATE 6



OHIO RIVER
HIGHWATER PROFILES

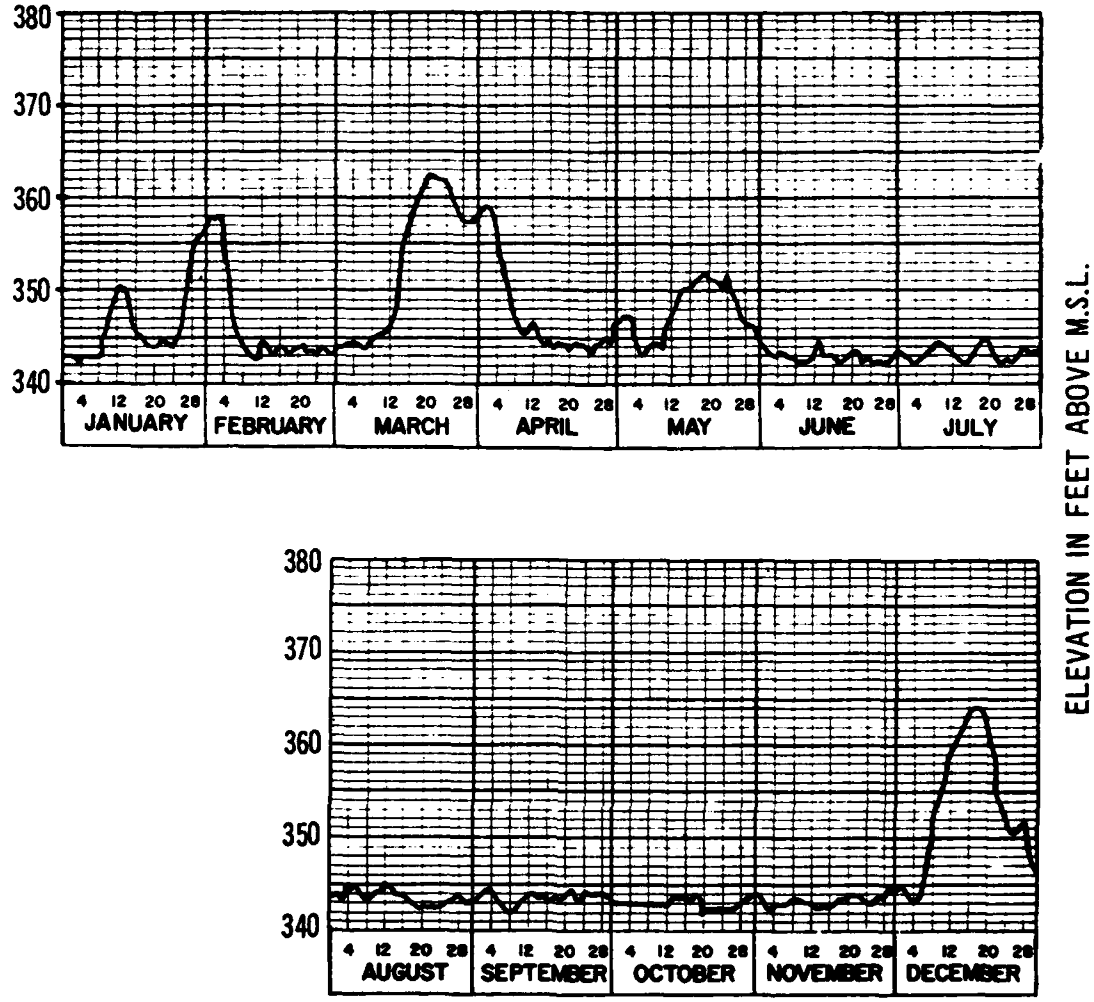
PLATE 7



1977

MOUNT VERNON, INDIANA
HYDROGRAPHS

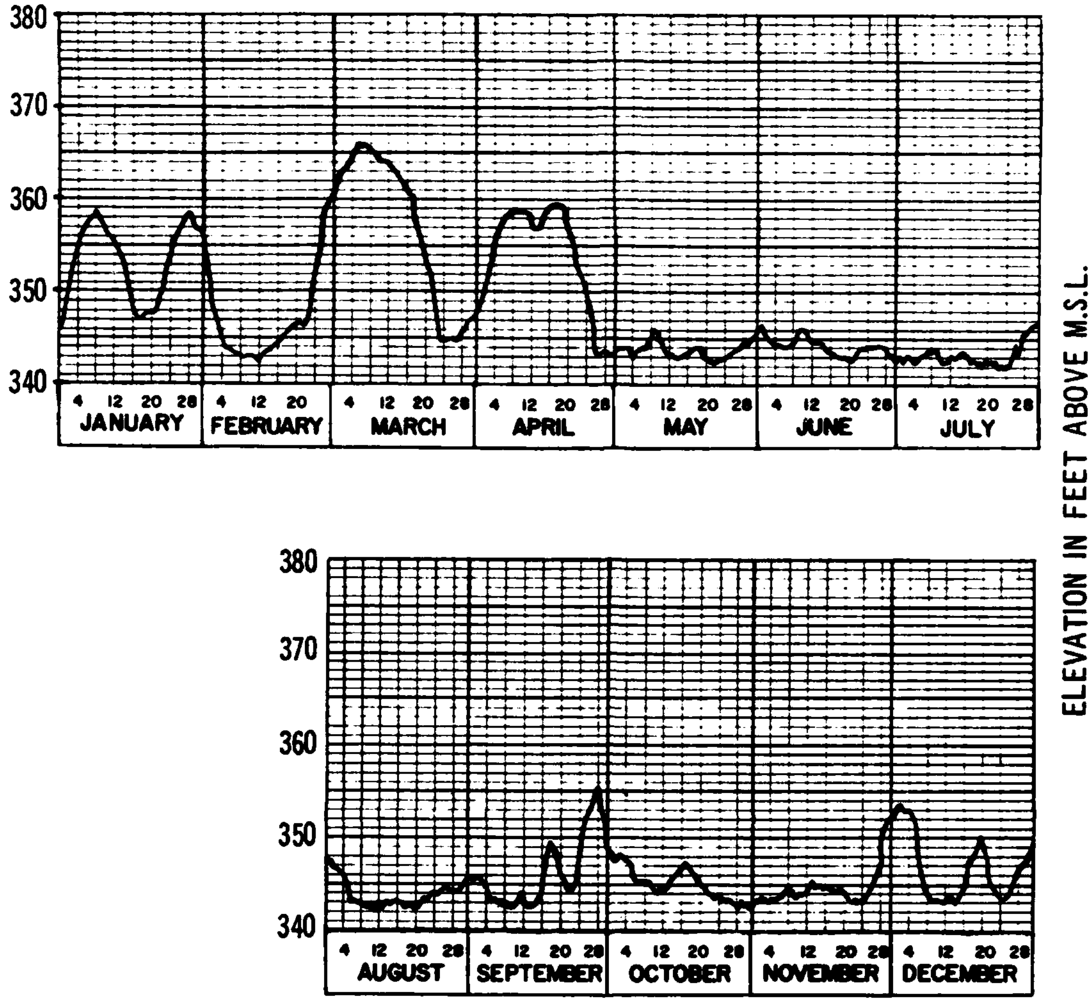
PLATE 8



1978

MOUNT VERNON, INDIANA
HYDROGRAPHS

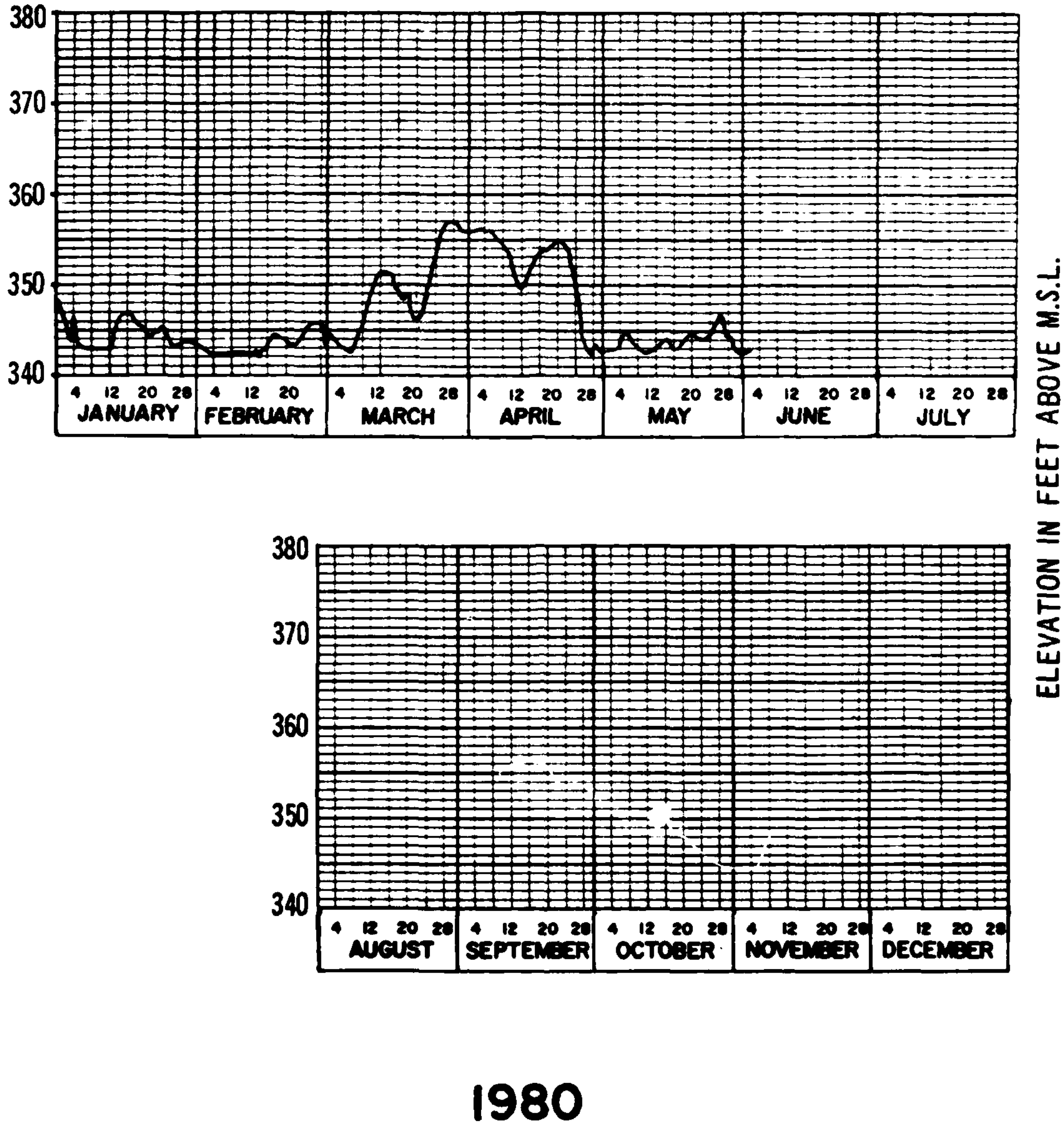
PLATE 9



1979

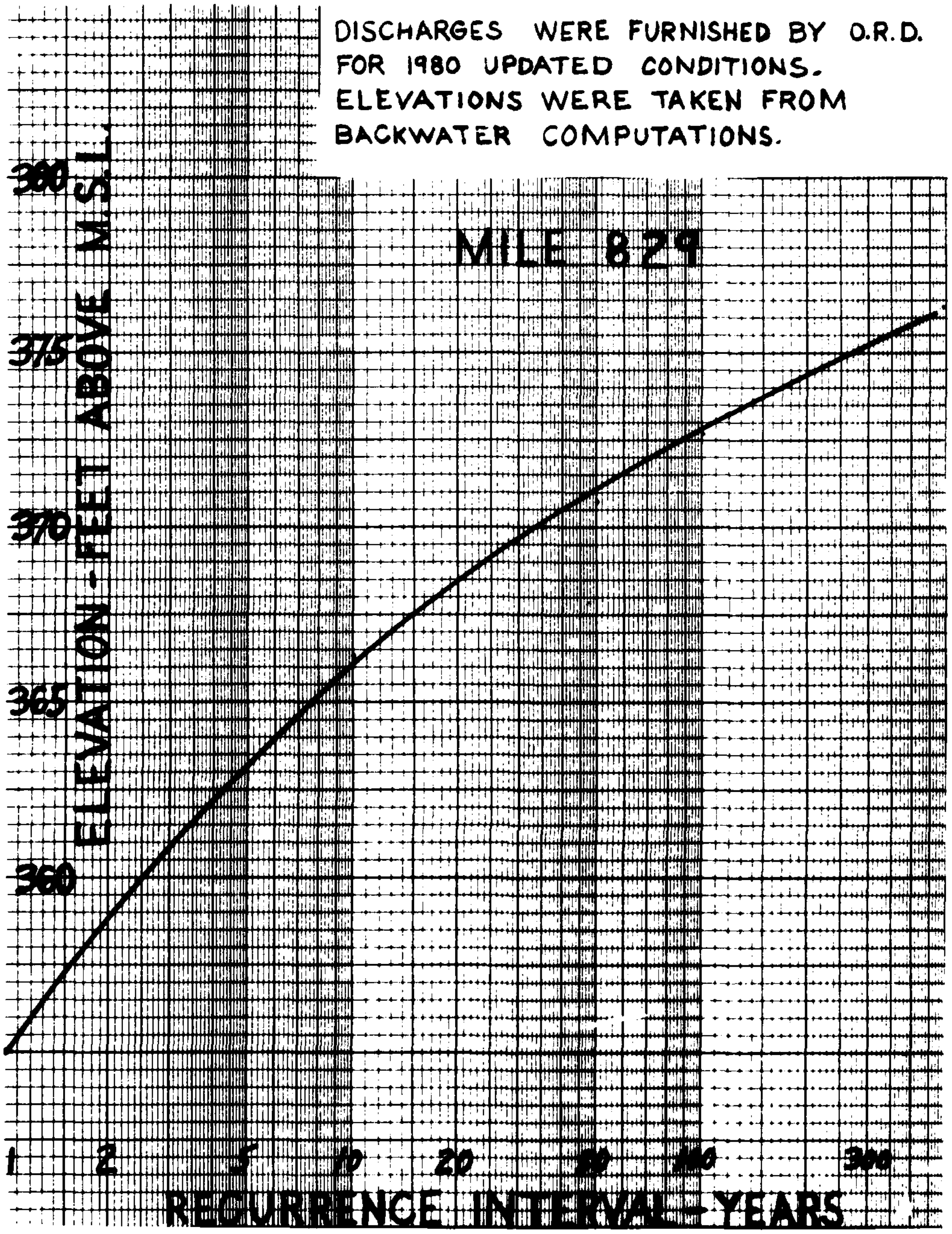
MOUNT VERNON, INDIANA
HYDROGRAPHS

PLATE 10



MOUNT VERNON, INDIANA
HYDROGRAPHS

PLATE 11



OHIO RIVER
ELEVATION FREQUENCY

PLATE 12